A

PHYSIOGRAPHY

PLATE I.

VESUVIUS AND SOMMA
with the
BAY OF NAPLES.

IDEAL SECTION THROUGH VESUVIUS
AND SOMMA.

Vesuvius.   Somma.

A TEXT-BOOK

OF

PHYSIOGRAPHY

OR

PHYSICAL GEOGRAPHY

BEING

An Introduction to the Study

OF THE

Physical Phenomena of our Globe.

BY

EDWARD HULL, M.A., LL.D., F.R.S.

DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.
PROFESSOR OF GEOLOGY IN THE ROYAL COLLEGE OF SCIENCE DUBLIN
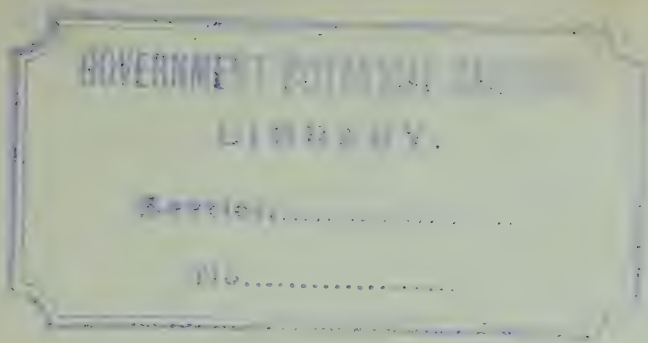
WITH

COLOURED PLATES, MAPS & ILLUSTRATIONS

LONDON :

C. W. DEACON & CO.

1888

AUTHOR'S PREFACE.

I N preparing this work, the Author has endeavoured to make it as complete as the limits assigned by the publishers would permit, regarding the subjects naturally falling under the designation of " Physical Geography," or the less definitive, though more simple term of " Physiography."

With this purpose in view, it was found necessary to give some account of the Earth as a member of the Solar system, though without trenching further than could be avoided on the domain of Astromony. Some reference also was considered necessary to the early condition of the Globe, in which the subject is naturally connected with structural Geology ; and, these fundamental problems having been disposed of, the way was clear for the consideration of the physical phenomena observable on
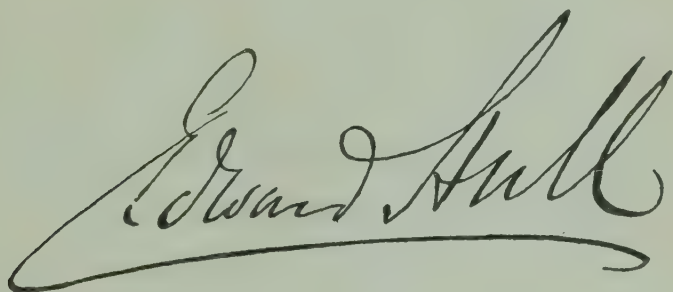
Preface.

the surface of the earth as at present constituted. So
wonderfully linked together are all the parts of this stu-
pendous whole, to which we give the name of *NATURE*,
that it is impossible to deal with any individual section
of it, without in some degree calling in the aid of the
others. Even the organic and inorganic kingdoms are
so interdependent that the subject handled in this work
would have been considered somewhat incomplete, had
no reference been made to the distribution of animal and
plant life on the Earth's surface; and, consequently,
several concluding chapters have been appropriated to this
most interesting and comprehensive subject, which for
its proper treatment would require the pages of a work
of several volumes. Where anything like full treatment
of a special subject was found inconsistent with the
scope of the present *opusculum*, references have been
given to works in which it will be found more fully
handled, and which are generally accessible to the class
of readers to whom the present book is mainly addressed.

In conclusion, I have to express my obligations to
several friends who have given me their valuable assist-
ance when treating special subjects, amongst whom I wish

Preface.

specially to mention the names of the Rev. MAXWELL
H. CLOSE, F.G.S., for his kindness in revising those
portions dealing with Astronomical and Mathematical
problems; to Professor BARRETT, F.R.S.E., for revising the
pages dealing with the subject of Terrestrial Magnetism;
and to Mr. BURBIDGE, F.L.S., Curator of the Botanic
Gardens belonging to Trinity College, Dublin, for his
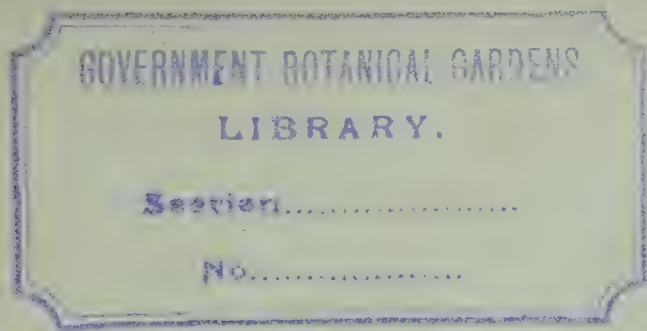contribution to the subject of Plant-distribution.

Edward Hull

ROYAL COLLEGE OF SCIENCE
DUBLIN,

December, 1888.

PHYSIOGRAPHY.

◆

TABLE OF CONTENTS.

PART I.

ASTRONOMICAL AND INTRODUCTORY.

CHAPTER I.

THE EARTH AS A PLANET IN THE SOLAR SYSTEM.

CHAPTER II.

THE EARTH AS A PLANET (Continued).

CHAPTER III.

LATITUDE AND LONGITUDE.

CHAPTER IV.

THE MOON.

PART II.

TERRESTRIAL PHYSICS AND DYNAMICS.

CHAPTER I.

THE EARTH.

CHAPTER II.

VOLCANOES.

CHAPTER III.

EARTHQUAKES.

PART III.

PHYSICAL FEATURES OF THE GLOBE.

— — —

CHAPTER I.

VARIETIES OF SURFACE FEATURES.

CHAPTER II.

THE OCEANS.

CHAPTER III.

HOW THE OCEANIC WATERS BECAME SALT.

CHAPTER IV.

CORAL ISLANDS AND REEFS.

CHAPTER V.

THE TIDES.

CHAPTER VI.

OCEANIC CURRENTS.

CHAPTER VII.

OCEANIC TEMPERATURES.

CHAPTER VIII.

CURRENTS OF THE AIR.

CHAPTER IX.

TEMPERATURE OF THE AIR.

CHAPTER X.

RAIN AND RIVERS.

CHAPTER XI.

SNOW AND GLACIERS.

CHAPTER XII.

UNDERGROUND WATERS AND SPRINGS.

CHAPTER XIII.

ARTESIAN WELLS AND UNDERGROUND WATERS.

CHAPTER XIV.

OTHER CONDITIONS OF TEMPERATURE OF WATER.

CHAPTER XV.

TERRESTRIAL MAGNETISM.

PART IV.

DISTRIBUTION OF PLANT AND ANIMAL LIFE ON THE GLOBE.

CHAPTER I.

INFLUENCE OF CLIMATE.

CHAPTER II.

BOTANICAL GEOGRAPHY.

CHAPTER III.

ZONES OF PLANT-LIFE ON THE HIMALAYAS.

CHAPTER IV.

CULTIVATED PLANTS AND CROPS OF TROPICAL, SUB-TROPICAL, AND TEMPERATE CLIMATES.

CHAPTER V.

DISTRIBUTION OF ANIMAL LIFE.

LIST OF COLOURED PLATES AND MAPS.

For Explanation of Plates, see page xxii.

————◆◆◆◆◆————

LIST OF FIGURES.

EXPLANATION OF PLATES.

PLATE I.

This plate is intended to represent Mount Vesuvius as it is at present, with the old crater of Somma, which constituted part of the dormant volcano before the time of Pliny. The Ideal Section is intended to illustrate the internal structure of the mountain—the sloping lines showing the beds of ash, lapilli, and lava-flows, traversed by vertical dykes of lava; in the centre is the principal funnel or throat through which eruptions take place from time to time.

PLATE II.

This is an Ideal Section through the Earth taken parallel to the Equator, in the Northern Hemisphere, intended to show the successive envelopes of which the crust and the deeper internal portions are composed. The continents of Europe, Asia, and N. America are also represented, as well as the intermediate oceans; but, it is almost needless to observe, they are not drawn to a true scale. Owing to the small size of the figure, it would have been impossible to represent them to a natural scale. The figure shows the manner in which volcanoes and volcanic isles are connected with the interior envelopes of matter. The condition of the centre of the earth is only conjectural.

PLATE III.

This plate requires very little description, as it speaks for itself. The depths of the ocean are represented by different shades of blue; the lightest being depths down to 500 feet; the next, down to 2,000 feet; the next, down to 5,000 feet; and the deepest shade, still greater depths. The steepest gradient occurs immediately to the westward of Cape Clear, and the bed of the ocean reaches a depth of 15,700 feet at a distance of 400 miles from the land. The curved lines (co-tidal lines) represent successive positions of the summit of the tidal wave at every successive hour.

PLATE IV.

The blue lines represent the path of the Atlantic Warm Currents, and the arrows the direction of flow. The red lines show the position of the Cold Arctic Currents, flowing southwards and ultimately disappearing below the warmer and lighter surface currents, including the Gulf Stream.

PLATE V.

This is a Chart of the World on Mercator's Projection, showing the position and direction of the two great systems of air currents which are constantly circulating round the surface. The arrows show the direction of the wind which is necessarily more constant over the ocean than over the land.

PLATE VI.

The two Maps of the British Isles and adjoining areas are taken from the Weather Charts issued daily from the Meteorological Office in London. As they are intended merely for illustration of the connection between the direction of the wind at any time and the barometrical pressure, the particular day is immaterial. The curved lines on Map 1 show the range of the Isobars from the centre of depression at Aberdeen to the highest line of pressure off the coast of Spain. The direction of the wind, in Map 2, is indicated by the curved lines and the arrows. The conditions are cyclonic.

PLATE VII.

In this Climatological Map of the Globe the wavy lines are intended to show, approximately, the annual mean temperature of the localities crossed by each. It will be observed that the region of highest mean temperature (80° Fahr.) lies along the Equator, and the successive mean temperatures follow, in descending order, lines somewhat parallel to those of Latitude. The most remarkable deviation from this parallelism is to be seen in the N. Atlantic Ocean, the effect of the Gulf Stream, as described in the text.

PLATE VIII.

This Map, taken from one by Professor Hennessy, F.R.S., shows the effect of proximity to the sea upon the annual mean temperature over the region of the British Isles. It will be observed that the lowest mean temperatures are experienced in the interior of these islands.

PLATE IX.

This Plate is intended to show, by different depths of colouring, the amount of annual rainfall over the area of the British Islands. The amount varies considerably in different years. It will be observed

that the mountainous districts towards the west of these Isles receive the greatest amount of rain, owing to the prevalence of the S.W. winds, which come, charged with moisture, from the Equatorial regions, and precipitate the rain upon the mountain slopes. The smallest rainfall is over the district of East Anglia.

PLATE X.

In this Map the relative levels of various portions of the British Isles are indicated by successive depths of colouring. The course of the Tidal waves is also shown on a larger scale than in Plate III. It will be observed how the co-tidal lines flow into both the Irish Sea and the North Sea from opposite directions, ultimately meeting in these waters. The position of the summit of the tidal wave, or high-water, at each successive hour, is shown by the figures I., II., III., &c.

PLATE XI.

This Map of the Glacier of the Allalein illustrates the phenomena of glaciers generally, including the *Nevée*, where the snow passes into glacier ice; the lateral and terminal moraines; the glacier-river issuing forth at the foot of the ice; and a glacier-lake—the Matmark See—formed by moraine embankments, and receiving from time to time blocks of ice, detached from the glacier itself, which float away like small ice bergs. The parallel lines show the veined structure in the ice. The Map is copied from the late Prof. J. D. Forbes' *Glaciers of the Alps*.

PLATE XII.

In this plate, copied by permission from Prof. Prestwich's *Geology* we have a representation of the manner in which icebergs are formed in the Greenland Sea. A large glacier, which may be that called after Humboldt, is seen descending from the interior of the continent and protruding out to sea. Owing to the buoyancy of the ice, large masses break off from time to time and float away as bergs. As they melt, blocks of rock, which they have carried down from the interior, are discharged and fall upon the rocky floor of the Greenland Sea, shown by the brown-colored part of the drawing. We must suppose that the bed of this arm of the Atlantic is thickly strewn with such blocks, together with smaller stones and mud.

PLATE XIII.

This Map is intended to show the magnetic variation of the Compass over the region of the British Isles. At each point crossed by the same lines the variation is the same, and is everywhere westerly. The Map is drawn for the year 1888; but as the variation is constantly progressing, though slowly, it will only be correct for a limited time.

PHYSIOGRAPHY.

PART I.

ASTRONOMICAL and INTRODUCTORY.

CHAPTER I.

THE EARTH AS A PLANET IN THE SOLAR SYSTEM.

A.—The Position of the Earth in the Solar System.

THE Earth being a member of the Solar System, it is desirable that, before entering upon the discussion of terrestrial phenomena, we should devote some space to the consideration of its relations to the sun and other celestial bodies. The Earth is one of the planets, revolving round the sun in an ellipse, in one focus of which the sun is situated.* This revolution is

---

* According to the First Law discovered by Kepler.

C

completed once a year of 365¼ days, during which time the path of the earth varies in distance from the sun ; but the mean distance of the earth's orbit may be taken at 92,380,000 miles.

B.—THE ECLIPTIC, OR PLANE OF THE EARTH'S ORBIT.

That the earth performs its revolution round the sun in the plane of a closed curve, appears from the fact that it returns to its place in the celestial sphere at the end of about 365¼ days. This curve is a great circle lying in a plane which passes through the centre both of the earth and of the sun; and, being that in which eclipses necessarily occur, has received the name of the " Plane of the Ecliptic." This plane, extended throughout the region of the Solar System, is that in or near which all the planets, except a considerable proportion of the minor ones, perform their revolutions.

The zone within which the planetary bodies, except those now mentioned, perform their revolutions round the sun is called " the Zodiac," and it extends to about eight degrees on each side of the ecliptic. If we divide the ecliptic into twelve equal portions, beginning at the vernal equinox, and then draw through each point of division a great circle perpendicular to the ecliptic, these circles will divide the zodiac into twelve equal parts.

These are *the twelve signs of the zodiac*, and are called after the constellations which formerly corresponded nearly with them, beginning with *Aries* and ending with *Pisces.* The " first point of Aries " is that from which the longitude (as also the right ascension) of any star or heavenly body has always been reckoned. It is the point in the heavens of the vernal intersection between the celestial equator and the ecliptic; but not being absolutely a fixed point in space, it has changed its position on the ecliptic backwards into the neighbouring constellation of *Pisces* ; for convenience sake, however, astronomers still retain the old name.

C.—THE EARTH'S ROTATION ON ITS AXIS.

Besides the motion through space, the earth rotates on an axis, the extremities of which are the North and South Poles ; and it completes one revolution in a day of twenty-four hours. The direction of rotation is from west to east, giving rise to the daily phenomena of the rising and setting of the sun and of other heavenly bodies. The greatest velocity of rotation is at the equator, where it amounts to a little over a thousand miles an hour.

D.—THE EQUATOR.

RIGHT ASCENSION AND DECLINATION.

The Terrestrial Equator is a great circle, whose plane, passing through the centre of the earth, is at right angles to the earth's axis of rotation. Hence between the North and South Poles and the equator, there is a distance of 90 degrees. The celestial equator is determined by the extension of the terrestrial equator into the celestial sphere, and the place of a star in the celestial sphere may be determined by its right ascension and declination; its right ascension being the angular distance on the celestial equator between the first point of Aries, or the vernal equinoctial point, and the intersection with the equator of a great circle drawn through the celestial object at right angles with the equator; and the declination of the object being its angular distance from the equator. When once the place of a star has been accurately determined and recorded, it becomes a definite point of measurement, from which the position of any heavenly body (such as a comet for instance) can be determined. Owing to the great distance of the sun, and the still greater distance of the stars, as compared with the semi-diameter of the earth, the celestial equator is assumed to coincide with a plane passing through the place of the observer.

E.—Inclination of the Plane of the Ecliptic to that of the Equator.

The plane of the ecliptic is inclined to that of the equator, at an angle which is called "the Obliquity of the Ecliptic," and is equal to about 23 degrees 27 minutes. The possible limits in the variation of this obliquity, calculated originally by Laplace, and afterwards by Stockwell, are as follows :—

Least . 21°, 58′, 36″.
Greatest 24°, 35′, 58″.

The great importance of this obliquity in relation to the seasons will be explained in the next chapter.

F.—The Poles. Precession and Nutation. The Pole Star.

The earth's surface is divided by the terrestrial equator into two equal portions, in the centre of each of which is situated one of the poles. These two portions are called the Northern and Southern Hemispheres respectively, and their centres the North and South Poles, which are the extremities of the earth's axis of rotation. This axis preserves a *nearly* constant inclination to the plane of the ecliptic, according to well-known mechanical laws ; but the axis has a retrograde conical motion, in consequence

of which the poles describe small circles on the celestial sphere of 23 degrees, 27 minutes angular radius about the poles of the ecliptic, completing the revolution in about 25,700 years. This causes the retrograde revolution on the ecliptic in the same period as that of the points of intersection of the ecliptic and celestial equator, or the equinoctial points, which movement gives rise to "the precession (in time) of the equinoxes." The inclination of the axis to the plane of the ecliptic, is, however, subject to a slight periodic change, determined by Bradley, owing to which the pole describes an ellipse about its mean place, the major axis of which subtends an angle of 18·45 seconds. The periodic time of describing this ellipse is 18·66 years, which, as it coincides with that of the revolution of the moon's nodes, is clearly referable to the disturbing influence of our satellite. *This* motion of the poles gives rise to the phenomenon of "nutation." *

The celestial pole is the prolongation of the earth's polar axis into the celestial sphere, just as the celestial equator is the extension of the plane of the earth's equator into space; and it might have been supposed that amongst all the stars lying in the direction of the North Pole, one would be found to coincide with the celestial pole itself. This, however, does not happen to

---

* For a fuller explanation of these movements, the reader is referred to Ball's *Elem. of Astronomy*, p. 319, also *The Story of the Heavens.*

be the case ; but there is a bright star whose position is very close to that of the celestial pole, and which has therefore received the name of the Pole Star. This star is α of the constellation *Ursa Minor*, and is very nearly in a line with α and β of *Ursa Major*, which have consequently received the name of " the Pointers." The angular distance of the Pole Star from the pole is about 1½ degrees.

The star *Polaris* (α of *Ursa Minor*) will be useful as a pole star for a long time to come, but in consequence of the above mentioned motion of the earth's axis, which causes the " precession of the equinoxes," the North Pole will have moved in about 12,000 years to the extent of 47 degrees away from that star.

The determination of the point in the celestial sphere which coincides with the Pole is important for finding the polar distance of a body and determination of latitude.*

G.—The Atmosphere.

The earth is completely enveloped by an invisible medium called the Atmosphere. To whatever height we ascend upon mountains, the air is still found to be present.

---

* The position of the celestial pole in reference to the star *Polaris* is shown in Proctor's *New Star Atlas*, plate I.

We feel certain that there is a limit to this atmosphere, but the height to which it extends into space is far beyond that to which we can attain, though we can ascertain its amount with some degree of approximation. That it has weight (or pressure) can be shown by means of the barometer, as the column of mercury steadily falls as we carry the instrument from the plains up the mountain sides; an experiment first performed by Blaise Pascal about the middle of the seventeenth century, on the Puy de Dôme, in central France. This atmosphere is composed of oxygen and nitrogen, in the proportions, by volume, of 20·81 of the former to 79·19 of the latter,* and is necessary to combustion, and to the support of plant and animal life.

---

* By weight the proportions are 23 oxygen and 77 nitrogen.

CHAPTER II.

THE EARTH AS A PLANET (Continued.)

A.—The Seasons. Explanation of the Changes
therein.

We know from experience that the periods of summer
and winter alternate in the northern and southern hemi-
spheres; thus the summer season in Australia corres-
ponds with that of winter in the British Isles and Europe.
Another observation with which we are also familiar is
the apparent change in the meridian altitude of the sun
as regards our place on the earth's surface at different
times in the year. Thus, in mid-winter (about the 21st
December) in each year, the sun only rises to a very
small extent (about 15 degrees near London), and for a
short period, above the horizon, and we have short days
in the British Isles; on the other hand, in mid-summer
(about the 21st June), the sun reaches its highest ele-
vation above the horizon (about 62 degrees near London),

and we enjoy a long day and correspondingly short
night. In higher latitudes the effects of these recurrent
changes in the altitude of the sun are intensified ; and
within the Arctic circle (latitude 66° 33′ N.) during
the periods of the sun's extreme elevation and de-
pression, continual day and night is maintained for
shorter or longer periods, according to the proximity to
the Pole. Only those amongst us, who, like the Arctic
Navigators of Captain Nares' expedition, and others
before them, have passed a winter within a few degrees
of the Pole, can have any conception of the solitude
and rigour of this prolonged night.

The changes of the seasons may be thus explained :
Let us suppose, for a moment, that the plane of the
ecliptic were coincident with that of the equator; the result
would be that the light and heat derived from the sun
would fall directly on the equator and the narrow zone
lying on either side of it ; while the now temperate
regions would receive the slanting rays of the sun, and
those lying within the Arctic and Antarctic circles
would receive only a minimum of light and heat. At the
poles the sun would appear always on the horizon. Under
such conditions we should have a maximum of heat and
of cold at the equator and at the poles respectively, and
there would be no change of seasons all over the globe.
Such a distribution of heat and cold would have rendered
the surface of our globe, if not uninhabitable, certainly
far less conducive to the development of plant and

animal life than is at present the case under the existing beneficent condition of recurrent seasons. These conditions are due to the obliquity of the plane of the equator to that of the ecliptic; owing to which the sun, in its apparent annual journey round the ecliptic, is alternately for half the year north of, and for the other half south of, the equator; imparting more and less, respectively, than the average amount of heat to our northern hemisphere; and, correspondingly so, with the southern hemisphere. The real motion is, of course, that of the earth itself round the sun, while the earth's axis of rotation remains sensibly parallel to itself.

As the result of these physical conditions, the heat of the sun during the alternate half-years is distributed over a much wider area of the globe's surface than would have been the case under the conditions first supposed ; while the mean temperatures of all parts of the earth are rendered more equable, and better suited to afford favourable conditions of development to the races of animals and varieties of plants which inhabit it.

This alternation of the seasons will be rendered more clear by referring to the following figure :—
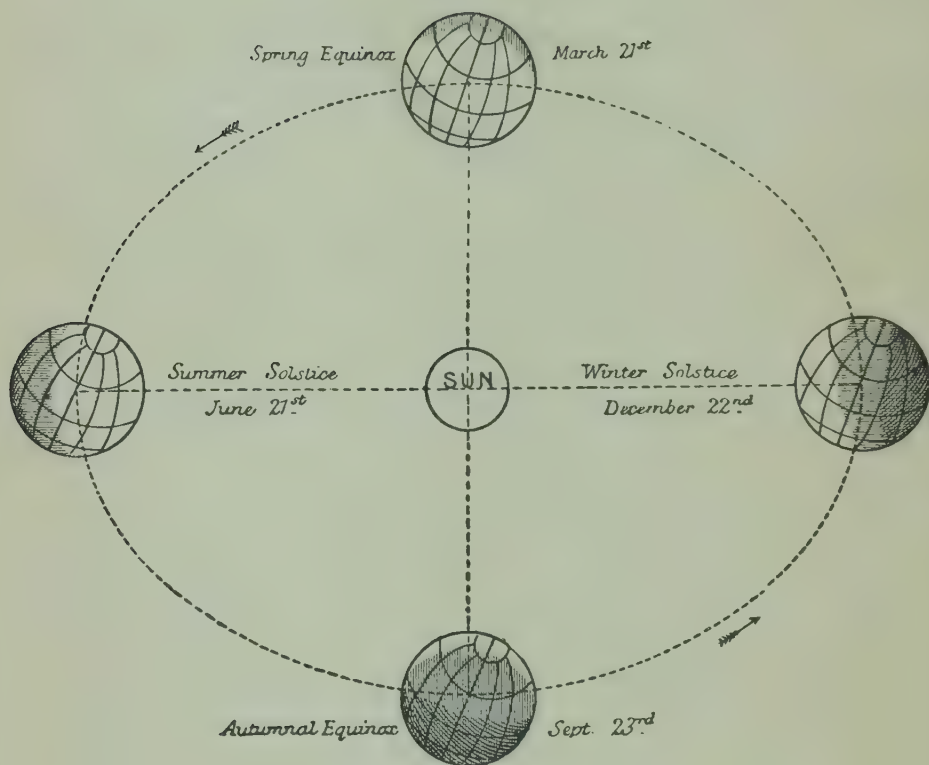
FIG. 1.—DIAGRAM TO SHOW THE SEASONS IN THE NORTHERN
HEMISPHERE.

The Earth is shown in four different parts of its orbit, in which
the axis of rotation is seen to retain a position parallel to itself
The portions of the earth receiving the direct rays of the sun at the
different periods are left unshaded.

B.—THE TROPICS OF CANCER AND CAPRICORN. THE ZONES ON THE EARTH'S SURFACE DEPENDENT ON ASTRONOMICAL CONDITIONS.

The tract on the earth's surface, every part of which lies directly under the sun's rays during some part of the year, is bounded by the tropics of Cancer, lying to the north of the equator, and of Capricorn to the south of it. Two parallels of latitude, each about 23 degrees 27 minutes distant from the equator, mark the limits of the sun's excursions in declination both north and south. Every part of this broad belt is subject, at some time during the year, to the vertical rays of the sun, and is called the Torrid Zone. Between the tropics and the Arctic and Antarctic circles are included the broader belts over which the sun's rays are always more or less slanting; these are called the North Temperate and South Temperate Zones; and beyond lie the Arctic and Antarctic regions on which the suns rays fall almost tangentially, and from which, during a portion of the year, they are absolutely excluded. It will thus be seen that these great zones into which the earth's surface has been divided are by no means arbitrary, but depend for their limits upon definite relations between the planes of the equator and that of the ecliptic. As a necessary consequence of the difference in the amount

of the sun's heat distributed over these zones, the animal and plant life undergoes a marked variation in passing from one zone to the other; although, through the agency of man, these variations have been reduced in extent as compared with those which would have prevailed had natural causes been allowed to hold uncontrolled sway.

CHAPTER III.

LATITUDE AND LONGITUDE.

A.—Definition.

The position of any point on the earth's surface may be determined by the intersection of two imaginary lines, those of latitude and longitude. For a ship at sea this may be the only means of identifying its place on a map, as all land objects may be out of sight; but even for places on land the same method of determination is highly advantageous, as the determination of the latitude and longitude of any place provides an universal standard of reference, independent of local changes, or of possibly conflicting names as points of reference.

B.—Mode of determining Latitude by observation of the Pole Star.

The latitude of a place is the angular distance from the equator, measured on a great circle passing through

that place at right angles to the equator, and it can be determined either by observations of the sun's altitude by day or that of the Pole Star by night,* taken by an astronomical instrument, such as the sextant. By the following geometrical problem it can be shown that the altitude of the pole above the horizon is equal to the latitude of the place (Fig. 2†). Let c represent the centre of the earth. Through c draw a line, c p, pointing to the pole of the heavens. This line cuts the surface of the earth at the North and South Poles, respectively. Through the centre of the earth draw a plane, c h, perpendicular to the axis. This plane, as already mentioned, cuts the surface of the earth
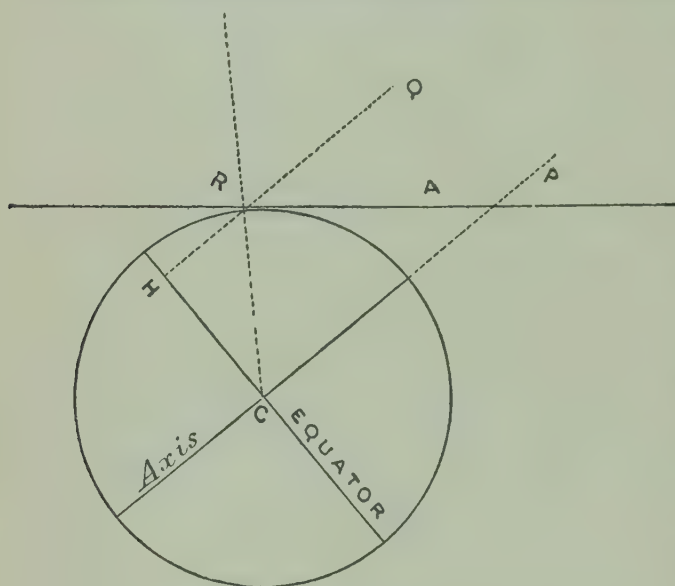
FIG. 2.—DIAGRAM TO SHOW HOW THE LATITUDE OF A PLACE IS ASCERTAINED BY OBSERVATION OF THE POLE STAR.

---

in a great circle—the equator. Let R be the place of the observer, then the line R C, drawn to the centre, will make with C H an angle, which is that of the latitude. Owing to the distance in the celestial sphere of the Pole, a line, H R Q, drawn parallel to C P will be the direction in which the observer will see the Pole. Let R A be the tangent plane at R, then A R C is a right angle, and Q R A + H R C are together equal to a right angle. From this it follows that Q R A = R C H; in other words the angle of altitude of the Pole is equal to that of the latitude of the place of observation; whence it is evident that the altitude of the equator where it crosses the meridian is equal to the co-latitude of the place of observation.

C.—Mode of determining Latitude by observation of the Sun.

In the case where the latitude is determined by observation of the sun's meridian altitude, we get more immediately the co-latitude of the place of the observer, and thence the latitude, allowing of course for the sun's declination, which is given for each day of the year in the *Nautical Almanack*.*

---

* Issued from the Royal Observatory at Greenwich; and which will also be found in that very useful Annual, *Whitaker's Almanack.*
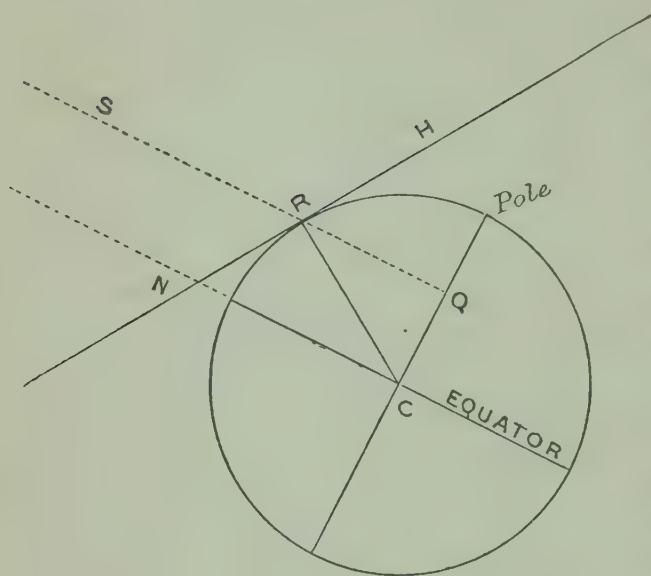
FIG. 3.—DIAGRAM TO SHOW HOW THE
LATITUDE OF A PLACE IS ASCERTAINED
BY OBSERVATION OF THE SUN'S MERI-
DIAN ALTITUDE.

Suppose the sun to be directly over the earth's equator, as it is at the equinoxes. Then let R be the place of the observer, H the plane of the horizon, E the equator, and C centre of the earth. Then the angle N R C equals 90 degrees, and S R N, the meridian altitude of the sun, is the complement of Q R C, and therefore is equal to R C Q, the co-latitude, then $90° -$ S R N equals the latitude. At other times than the equinoxes allowance for the sun's declination is required, according as the sun is north or south of the equator. Then lat. $= 90° -$ A $+$ D in the former case, and lat. $= 90° -$ A $-$ D in the latter case, where A is the sun's meridian altitude, and D its declination.

A star may be used as well as the sun, in a precisely similar manner, for the determination of latitude; its

meridian altitude (A) being obtained by observation, and ts declination (D) taken from the *Nautical Almanack*, or other source of information. Of course allowance has to be made for refraction, etc.

The latitude can be obtained by less simple methods without having to depend on the visibility of the sun or star when at its meridian altitude.

D.—Mode of determining Longitude.

The Longitude of any place is the arc on the equator, or any parallel circle, intercepted between the meridian passing through the place, and any fixed meridian recognised as a point of departure. In the case of the British Isles, the meridian of Greenwich Observatory is the recognised point of departure, and longitudes are reckoned to 180 degrees eastward or westward of Greenwich. The determination of longitude can be easily made at any station within telegraphic communication of an observatory. As the telegraphic signal is practically instantaneous, it can be ascertained what is the intervening period, measured in mean solar time, between the transits of the mean sun across the meridians of the two places, or between such transits of a star measured in sidereal time. This gives the difference between the mean solar, or the sidereal, time of the place and of the observatory. The difference of longitude

will then be reckoned at the rate of fifteen degrees per mean solar or sidereal hour, respectively ; this amount being obtained by dividing the number of degrees in the circle, namely 360, by 24, the number of solar or sidereal hours in a solar or sidereal day.

When the place is not within telegraphic communication, as is the case at sea, the longitude may be determined by observations of the sun by day, or of the moon by night. In the former case the process is as follows : Suppose we sail from the London Docks on board a ship bound for some port in the American continent. Previous to starting the ship's chronometers are accurately set to Greenwich time, they having been carefully regulated; or, rather, their rates noted for the purpose of correction. At some spot on the Atlantic, and the sun being visible, the captain is desirous of determining his position of longitude west of Greenwich. For this purpose he takes two equal altitudes of the sun, one a little before, the other a little after, noon, noting the time shown by the chronometers at each ; * then, the instant of mean noon is that half way between, after allowance has been made for the sun's change of declination in the interval between the two observations, and for the equation of time.

For this method of obtaining local time, knowledge of the latitude of the place is not necessary ; but if this be

---

* This may require repeated observations instead of two, for greater accuracy.

known, the sun's declination at the time of observation being known from the *Nautical Almanack*, the local time can be obtained by taking a single altitude of the sun.

The determination of longitude may be effected also by the method of lunar distances, without having to depend on chronometers for Greenwich time. In this case, Greenwich time is ascertained by taking the angular distance between the moon, as seen from the centre of the earth, and some fixed star which lies along its path, or the sun, and finding from the *Nautical Almanack* at what instant of Greenwich time the moon and the star, or sun, should be at that distance apart.* The distance between the moon and various suitable celestial objects, including the sun, is given by that almanack for every three hours throughout the year,† and the Greenwich time of the distance in question can be easily obtained by proportion, and compared with the local time of the observation.

---

* The true distance as seen from the centre of the earth is obtained by clearing the observed distance from parallax and refraction.

† Except for the few days in each month when the moon is too close to the sun to be visible.

CHAPTER IV.

THE MOON.

A.—Its Nature, Form, and Distance from the Earth.

The moon is, in all probability, a prolate ellipsoidal mass, whose longer diameter is directed towards the earth, and is composed of materials similar to, if not identical with, those of which our globe was originally formed. At an immeasurably distant period the moon was, doubt-less, thrown off from the mass of the globe itself, ultimately to revolve round the earth in an orbit which has been slowly enlarging ever since, and will continue to do so for a long time. The present mean distance of the moon from the earth is about 60 times the earth's equatorial radius, or 237,770 miles ; but, as the orbit is far from being circular, the distance fluctuates between 56 and 64 times the equatorial radius.* The moon may be said

---

* It will enable the reader to form some conception of the enormous magnitude of the sun's circumference, when it is stated that if the earth's centre occupied a position coincident with the centre of the sun, the orbit of the moon. even at its greatest distance, would be contained within the volume of the sun itself.— Ball, *loc. cit.* p. 228.

to describe a great circle in the celestial sphere round the earth in a period of about 27.3 days, the plane of which circle is inclined at an angle of 5° 9′ to that of the ecliptic, and revolves retrogressively, so that its nodes complete the circuit of the ecliptic in 18.66 years, as referred to already. The evident consequence of this is that the inclination of the plane of the moon's orbit to that of the equator varies between 23° 27′ − 5° 9′, and 23° 27′ + 5° 9′, or between 18° 18′ and 28° 36′ (23° 27′ being the inclination of the ecliptic to the equator.)

B.—Periodic Time of the Moon's Rotation.

The period of the moon's rotation on its axis exactly coincides with that of its revolution round the earth, in consequence of which only one face of the moon is displayed to the inhabitants of this world ; and we can only conjecture that the opposite face must be, on the whole, similar to that which is visible. In consequence of this coincidence, it is sometimes difficult for a person to realise that the moon rotates at all. But a simple mode of illustration is at hand ; for, if a person places a ball, or other object, in the centre of a round table, and then walks round the table whilst keeping his face constantly turned towards the object, he will have performed a complete revolution and rotation simultaneously on regaining his starting point.

C.—Nature of the Moon's Surface.

Owing to the absence of any appearance of cloud and twilight over the moon's surface, even when seen by the aid of the most powerful telescopes, it is surmised that there is an entire absence of those elements which support life and verdure on this world of ours : namely, water and atmosphere. If either does exist, the water must be in very small quantity, and the atmosphere in a condition of extreme tenuity. Seen through the telescope the surface of the moon suggests the impression of a rigid mass over which are distributed large numbers of extinct volcanic craters, some of vast dimensions and profound depth, exceeding, perhaps, those anywhere existing on the surface of our globe.* Generally, the circular rims of the craters, which stand out in bright light from the surface a little after sunrise, surround a dark interior tract, from the centre of which a conical hill projects, somewhat as the central cone of Vesuvius emerges from a rugged plain of lava bounded by the walls of the more ancient crater of Somma. These appearances are repeated over a very large portion of the face of the moon. There are no appearances which indicate the presence of extensive lakes or seas, or of

---

* Except, perhaps, those submerged under the waters of the Pacific Ocean on which are supposed to be built the coral structures known as " atolls."

large rivers; consequently, the results of aqueous erosion, or "denudation," have no representation on the moon's surface; and a prolonged survey of a portion of the disc through a telescope of the largest dimensions tends to leave the impression that we are gazing on a celestial body from which all life and all motion is absent : a body, once the scene of volcanic operations on a stupendous scale, but which has crystallized into a rigid mass of once molten matter, from which, even the energy of vulcanicity has long since disappeared.*

The volcanic districts of Mont Dor and Auvergne present an appearance having, perhaps, the nearest resemblance to the surface of the moon to which we can point on our globe; but this resemblance is only partial, inasmuch as the features of this part of Central France have been largely modified by the action of rain and rivers, which appear to be absent from the moon's surface, as we have already observed.

D.—Eclipses of the Moon.

Eclipses of the moon are caused by the intervention of the earth between the moon and the sun, and the

---

* The author had, some years ago, the opportunity, through the courtesy of the constructor, Sir Howard Grubb, of seeing a portion of the moon's disc through the great Vienna refracting telescope in Dublin, before it was despatched to its destination. The appearance of the surface was like that of a plaster cast.

passing of the moon through the shadow of the earth: they may be either partial or total. This latter phenomenon takes place when the centres of the three celestial orbs are in a direct line, or nearly so ; and, like other eclipses of given magnitudes, is recurrent at intervals of 18 years and 11 days.

In a total eclipse, however, notwithstanding that the shadow of the earth is thrown over the whole of the moon's face during the period of greatest obscuration, the moon itself is still visible, and is seen illuminated by a dull reddish light. This light is due to the refraction of the sun's rays, which, in passing through the earth's atmosphere, are deflected into the earth's shadow and thrown over the moon's disc. This appearance of the moon during the recent eclipse on the night of the 28th January, 1888, will not soon be forgotten by those who witnessed it.

E.—Density of the Moon as compared with that of the Earth.

Though there was, doubtless, an original physical connection between the moon and the earth, the density of the moon is less than that of the earth, the proportions being as follows :—

Density of the earth . . . 5·5 or 5·6
  ,,   ,,   moon . . . 3·1

This latter, as Dr. Haughton observes, is the density of basalt,* a rock which, very probably, largely enters into the composition of the moon's mass, being (in its several varieties) an abundant product of volcanic action on the earth.

From the character of the moon's surface, we are in fact warranted in assuming that the mass of our satellite is composed of such rocks as are formed by volcanic and plutonic action on the earth's surface. Such rocks are crystalline aggregates of felspar, pyroxene or hornblende, quartz, and iron in the condition of magnetite. Owing to the inferred absence of water, all those varieties of strata which are formed by deposition under water must be considered as absent in the moon, together with all organized animal or vegetable remains.

* *Lectures on Physical Geography.* p. 4 (1880).

PART II.

TERRESTRIAL PHYSICS AND DYNAMICS.

CHAPTER I.

THE EARTH.

A.—Form of the Earth.

SIR Isaac Newton first showed that the form of the earth must be that of an ellipsoid of revolution, by calculations based on his newly-established doctrine of gravitation.* He also determined the ratio of the axis of the earth, on the assumption that the earth is a homogenous fluid mass, rotating with its actual angular velocity. This determination was afterwards verified by Maclaurin.† That the earth was originally in the condition of a viscous or fluid mass owing to a high

---

* *Principia* (1687); Propositions 18, 19 and 20.

† Colonel Clarke's *Geodesy*. It is now known that the earth is not a homogenous mass, being denser in the central parts.

temperature, is a view almost universally admitted, and one which enables us to understand its form and structure. This view is not restricted to the earth and its satellite, but has been extended by Laplace to embrace all the bodies of the solar system, on grounds founded on the revolutions of these bodies round the sun in nearly the same plane, and also round their axes in the same direction.* As determined by Airy, the earth's polar diameter is 7,899·17 miles; its equatorial, 7,925·65 miles; the latter exceeding the former by nearly 26½ miles, so that the earth has a protuberance over 13 miles thick all round the equator, gradually diminishing to zero at the poles.†

B.—Structure of the Earth. The Crust and Interior Portion.

The exterior solid crust of the earth is composed of a great variety of materials, to which the general name of "rock" is applied, and which includes granite, porphyry, and various igneous masses, together with those which have been formed by deposition under water, such as slate, sandstone, limestone; and intermediate varieties, called "metamorphic" rocks, which include various gneisses, schists, quartzites, and crystalline marbles. These

---

* *Système du Monde* (1835).

† Newton's determination gave the difference between the two diameters as 229 to 230, or 34 miles instead of 26½.

various rocks are distributed under various forms, and under ever varying relations to one another, which it is the province of the geologist to investigate and explain;* and, although the nature of the basement floor of the rocks which appears at the surface is unknown, it may be inferred that it consists either of granite, or some similar crystalline rock of comparatively low specific gravity, resting upon a *couche* (or envelope) of denser molten matter, which reaches the surface from time to time through fissures in the superincumbent masses, and gives origin to various volcanic and igneous crystalline rocks. As a recent writer has well expressed it, we may feel almost certain that the earth was once wholly melted, and that it consists at present of concentric spheroidal shells (*couches*), each of equal density throughout, and of definite form ; such form having been determined by the velocity of rotation and law of density, coupled with the law of mutual attraction of all the mass.†

C.—Internal Tension below the Crust.

The crust thus formed and constituted has been constantly undergoing contraction, owing to the radiation of internal heat into space. This cooling process must have been more rapid at an early period of the earth's

---

* In the construction of geological maps, these various formations and varieties of rock are individually traced out and represented, in more or less detail, by differences in t he colours and signs used.

Rev. O. Fisher's *Physics of the Earth*, p. 18.

PLATE II.

Europe - Asian continent

Granitoid and stratified rocks

Viscous weld-matter

Viscous basic matter

Regio conditionis incertæ

Envelope of greater density

Envelope of medium density

Exterior lighter crust

Atlantic Ocean

Pacific Ocean

American continent

IDEAL SECTION THROUGH THE EARTH, TO SHOW
CONJECTURAL STRUCTURE OF THE CRUST AND THE
RELATION OF LAND AND WATER.

history than in more recent geological times. At present it is very slow; yet, that a higher surface temperature obtained even in late Tertiary periods is apparently manifest in the changes which have taken place in the distribution of land and water within those periods. How these changes have resulted from the secular cooling it is not difficult to explain. As the cooling proceeds, the crust tends to contract upon its internal molten envelope, thus setting up a tangential thrust of so powerful a nature as to cause the internal molten matter to be extruded through fissures in the solid crust. After the crust had become sufficiently thick and rigid, the subsequent contraction of the cooling interior would leave the crust too large for support, and thus it would be subjected to horizontal thrust, ultimately causing tension of the deep-seated crust. Such movements have apparently only taken place at long intervals, and over special areas, and may be considered as natural methods of restoring equilibrium when the tangential forces due to contraction have become too powerful for those of friction and gravity.*

---

* C. Davison and C. H. Darwin, *Phil. Trans. R. S.*, Vol. 178, p. 241.—Mr. C. Davison, starting with the results arrived at by Sir William Thomson, on the secular cooling of the earth (*Trans. Roy. Soc., Edinburgh*, Vol. 23), arrives at the conclusion that the folding by lateral pressure can only take place to a certain depth below the surface of the earth; at this depth folding vanishes; and passing downwards, folding gives place to stretching by lateral tension. This stretching he maintains, has been accompanied by cooling of the masses stretched. Mr. Davison also draws the conclusion that folding by lateral pressure was effected most rapidly in the early epochs of the earth's history, and since then, the total amount of rock folded in any given time decreases nearly in proportion as the square root of time increases. Professor Darwin in an appendix to Mr. Davison's memoir gives a general support to these views, and states that they are eminently in accordance with observation.

D.—Effect of the Contraction of the Earth
on velocity of rotation.

It is easy to show that the contraction of the body of
the earth must
tend to accel-
erate the ve-
locity of rota-
tion. Let the
adjoining fig-
ure (Fig. 4)
represent a
section of the
earth, and c be
the centre, or
position of axis
of rotation.
Then if we
describe a se-
ries of con-
centric rings
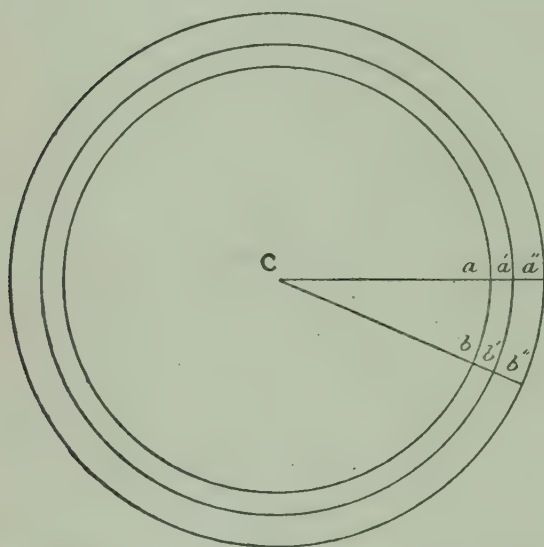
Fig. 4.—Diagram to show the acceleration
of the Earth's velocity consequent
upon its contraction.

round the axis, the linear rate of rotation will be propor-
tional to the radii $c\,a$, $c\,a'$, $c\,a''$, and the outer ring $a''\,b''$
will move faster than $a'\,b'$, and this faster than $a\,b$. As
each successive ring rotates with decreasing velocity as
we descend inwards, if the ring $a''\,b''$ be moved to $a'\,b'$,
and $a'\,b'$ to $a\,b$ during contraction, each will carry with it

the velocity due to its original distance from the centre, and thus cause acceleration of the whole mass. We shall see in a future chapter how this acceleration is counteracted by the tides.

E.—Mean Density of the Globe.

Experiments made on Schiehallion in Scotland, by Maskelyne; on Mount Cenis in the Alps, by Arago; as also by Baily, Cornu, and Baille, all go to prove that the mean density of the globe, as compared with pure water, is about 5.5. In the case of Airy's experiments at Harton Colliery, it was found that the second's pendulum at the surface gained 2·25 seconds daily on being transferred to the bottom of a pit 1,260 feet deep. The ratio of the forces of gravity at the surface and at the bottom of the pit is found by the following formula:—

$$2·25 = 86,400 \left(\frac{g'}{g} - 1 \right).$$

The increase of gravity expressed as a fraction of the whole amount is $\frac{1}{19200}$th, and gives a result of 6·56.[*]

The mean density of the earth, as determined by experiment, is only about twice as great as that of the

[*] *Phil. Trans. R.S.* (1856). Airy's results are in excess of those of other observers, and were founded on the rather uncertain assumption, viz.: that of the mean density of the upper part of the body of the earth. The Cavendish experiment is doubtless the most reliable. By this Baily arrived at 5·66 after great labour and care. Cornu and Baille arrived at a result of 5·56, working in the light of Baily's experiments.

rocks of which the outer crust is composed ; but, owing to the force of gravity, and the resulting pressure, the mean density of the globe formed of such materials ought to be enormously greater than is found to be the case. Thus, water at the surface ought to be as heavy as mercury at a depth of about 362 miles, or 13·6 times heavier; and ordinary rocks, such as granite, slate, sandstone or limestone, and basalt ought to have a density, at a similar depth, of 25 to 30 times that of the surface. From this it is clear that some agent must come into operation tending to counteract the effects of pressure ; this agent is, doubtless, heat.*

F.—Depth of Molten Matter below the surface.

The phenomena connected with the outflow of molten lava from volcanic vents, or from fissures of eruption, as well as the existence of intrusive crystalline rocks amongst sedimentary strata, all tend to show that, at some depth below the surface, the solid crust is under- lain by masses of molten matter, perhaps arranged in successive shells or *couches*, according to their relative densities. At the same time it must be recollected that the melting point of all bodies is raised by pressure,† so

---

* See *ante* p. 54.
† As Hopkins has shown by experiment in the case of several substances.

that as the pressure increases with the depth as well as the temperature, the question arises, at what depth will the rocks of the crust exist in a molten condition ? The question is more easily asked than answered ; for in the language of a recent writer, " in the chase of the increasing heat after the flying fusing point, *where* the former would overtake the latter, or whether it would overtake it at all, science is yet unable to answer."* It may, however, be urged in reply, that the heat *has* overtaken the fusing point, as the occurrence of molten lava in all periods seems conclusively to indicate.

G.—Internal Temperature of the Earth.

That the temperature of the crust increases with the depth is a proposition which is supported by observations on deep seated springs, on volcanic eruptions, and experiments in mines and deep borings. Numerous observations have been made in recent times with the view of determining the rate of this increase of temperature ; and the Committee appointed by the British Association for collecting information on this subject has presented nineteen Reports down to the year 1887, all tending to confirm the general conclusion as regards an actual increase, but showing varying results as regards

---

* Le Conte, *Elements of Geology*, p. 80 (Edition 1887.)

the rate of that increase. Professor Prestwich, who has analysed these returns, arrives at the conclusion that the mean rate of increase of temperature is as high as one degree Fahr. for every 47·5 feet in depth.* In the case of the observations taken at Rose Bridge Colliery, and extending down to a depth of 2,424 feet in horizontal strata, the rate of increase was found to be one degree of Fahr. for every 54·4 feet of depth.†

It is obvious that in estimating the rate of increase of temperature in any deep shaft or boring some invariable standard of departure must be used for each locality; inasmuch as the temperature of the surface varies considerably with the season of the year and other conditions. Such a standard is furnished by Humboldt's "Invariable Stratum." It will be evident that during the year there will be an alternating descent of heat from, and ascent to, the surface during the summer and winter months; the result of which is that, a point or stratum is reached at which the temperature is constant all the year round, and is nearly that of the mean annual temperature of the place. The depth of this stratum varies with the latitude, the conducting power of the rock, and the amount of difference of temperature of the hottest and coldest seasons.

---

* *Proc. Roy. Soc.,* Feb., 1885.

† The observations taken at this Colliery in 1869, appear to give normal results and will be found in *The Coal-fields of Great Britain,* 4th Edit. p. 488.

H.—Temperature of the " Invariable Stratum."

It is a matter of general observation that, at some little distance below the surface, the temperature of the ground, if protected from the outer air, is not subjected to the extreme variations of the seasons. Cassini found that the temperature of a thermometer inserted in sand and placed in the cellars below the Observatory of Paris, remained constant all the year round. At Greenwich, where the mean annual temperature is about 50 degrees Fahr., it was found (in 1858) that, in the case of the deepest of several underground thermometers placed 25 ft. from the surface, the extreme variations were 48·85 degrees to 52·27 degrees, giving a mean of 50·56 degrees ; a result differing by only about half a degree from the annual mean temperature. At a few feet deeper, or 40 to 50 feet, a constant temperature would have been attained.

Taking the case of the central parts of England, it may be assumed that the temperature of the " Invariable Stratum " may be taken at 50 degrees Fahr., and the depth 50 feet. This rule is easily recollected, and is sufficiently accurate for ordinary purposes of comparison.

CHAPTER II.

VOLCANOES.

A.—Nature of Volcanic Action.

As in some measure connected with the question of internal temperature, the subject of vulcanicity demands attention in this place. Volcanic eruptions with their attendant earthquake shocks have always been amongst the most terrific and destructive of natural phenomena. We have only to mention the first recorded eruption of Vesuvius, A.D. 79, so graphically described by the younger Pliny, by which the flourishing towns of Herculanæum and Pompeii were overwhelmed, as an example of the destructive effects of volcanic eruptions; and the great earthquake of Lisbon, A.D. 1755, by which a large portion of that city was devastated, as an example of similar effects from earthquake waves. Described in most general terms, a volcano consists of a fissure, or funnel, passing upwards through the crust to the surface, and generally terminating in a conical hill, with a cup or "crater" immediately over the funnel, through

which, when in a state of activity, molten lava, together with ashes, lapilli, and blocks of rock are extruded, or blown out through the action of the elastic force of gas and steam. Strabo recognised the connection between volcanic and earthquake phenomena, and considered volcanoes as safety-valves against destructive explosions of pent-up steam.

B.—Volcanic Action of Geological Times.

From the earliest geological periods down to the present day, volcanic eruptions appear to have taken place from time to time, as shown by the presence of sheets of lava and of ashes or tuff amongst the stratified formations. Not to go back very far, we find that the close of the Cretaceous period in the Indian Peninsula, was remarkable for the extensive outpourings of volcanic lavas which now go to form the extensive table-land of the Deccan to the south of the Indo-Gangetic plain, and cover an area of little less than 200,0co square miles; originally much larger.* In Tertiary times, vast eruptions of lava have taken place in Syria, Greece, Italy, Central France, the British Isles, and the western parts of the North American Continent. In the case of volcanoes of the Geological periods, only the "necks" or lava-filled funnels and fissures of eruption remain in the

---

* Medlicott and Blanford, *Geology of India*, part I., pp. 300 and 331.

form of isolated masses of trap penetrating the rocks, the craters and cones of eruption having been swept away by denuding agencies. But in many districts, such as those of Auvergne in Central France,* and the region of the Jaulân east of the Jordan, where volcanic action has long since ceased, the cones and craters still remain in excellent preservation.

C.—Structure of a Volcanic Mountain.

As a volcano originates in some fracture or fissure in the crust, when an explosion of gas and steam takes place, masses of fragmental matter, consisting either of lava or of rock torn from the sides of the fissure, are hurled into the air, and falling around the vent arrange themselves in the form of a cone with sloping sides, and containing in the centre a cup-shaped hollow called a " crater." Hence, in the greater number of cases, volcanic mountains assume the form of a truncated cone when viewed from some distance.† In a few cases, however, where viscous matter has been extruded through a fissure, the form of a dome is the result ; of which we have examples in the Puy de Dôme and the Grand

---

* Scrope, *Extinct Volcanoes of Central France*, (1858).

† Outlines of various Volcanoes will be found in Prof. Judd's work on *Volcanoes, what they are and what they teach*, p. 178 (1881). See also Phillips' *Vesuvius.* (1869) plate II, p. 176.

Sarcoüï in central France, and the Mamelon Cone in the Isle of Bourbon. Along with the fragmental materials may be intermixed sheets of solidified lava, which have been extruded from the vent, or some secondary orifice, and have poured down the sides when liquid; and these again may be penetrated in various directions by dykes of lava, which have been injected through fissures. It often happens, that upon the formation of a volcanic cone of loose fragmental matter, the crater afterwards becomes filled with heavy molten lava, and upon the walls of the crater becoming too weak to sustain the resulting pressure they give way, and the lava flows forth down the sides and inundates the plains below, often for long distances. Numerous examples of these ruptured craters and of their escaped lava streams may be observed in the Auvergne region of Central France, as well as in the Haurân, and are amongst the most striking features of both of these regions of former volcanic action.*

D.—DISTRIBUTION OF VOLCANIC MOUNTAINS.

It was observed originally by Arago, that nearly all the volcanic mountains of the globe are situated in close proximity to the ocean, or to some large inland sheet of

---

* See Schumacher's map of the Haurân and Jaulân in the *Quarterly Statement of the Palestine Exploration Fund*, January, 1888.

water.[*]   This is sufficiently clear in the case of the Italian volcanoes, of the volcanic islands of the Pacific, the Indian and the Atlantic Oceans, together with those of the adjoining continents of Asia and America.

In some regions, such as those bordering the Caspian, the Sea of Aral, and Lake of Van, where extinct volcanic mountains appear to abound, the extent of water was formerly much larger than at present ; and it seems not improbable that the cessation of volcanic action has kept pace with the withdrawal of the waters of the Central Asian Sea to their present more restricted limits.   This sea appears to have stretched from the Euxine along the northern base of the Caucasus, and to have included the Caspian and the Sea of Aral.[†]

E.—Lines of Volcanic Vents.

Amongst the most important lines of volcanic vents, either active or recently extinct, are :—

---

[*] The volcanic region of Central France is no exception to this, because the plain of Clermont, on its borders, was formerly the site of an extensive lake which has since been drained; and as regards the extinct volcanoes of the Haurân and Jaulân, it seems probable that they were in activity when the Jordan valley was occupied by the waters of a lake, which stretched from the Lake of Merom on the North, to a position several miles beyond the limits of the Dead Sea on the South. *The Phys. Geology of Arabia Petræa, Palestine, &c., Mem. Palestine Exploration Society*, p. 99, (1886).

[†] Dubois de Montpereux, quoted by Daubeny, *Active and Extinct Volcanoes* 2nd Edit., p. 367, (1848).

(1.` That of South America, stretching from Sarmiento on the south, along the Andes of Chili, Peru, and Bolivia, to the Isthmus of Panama. Here it sends off a branch toward the east, which is continued into the Antilles ; but the main line follows the coast of the Pacific into Mexico, Western America and the Aleutian Islands. Throughout the greater part of this line of country in North America, volcanic action only exhibits its secondary symptoms in the form of hot springs, geysers and sulphurous exhalations.

(2.) That of the peninsula of Kamtchatchka and the Kurile Islands, thence ranging through the Japanese, the Philippine, the Solomon and the Australasian Islands into the northern part of New Zealand.

(3.) From this branches the volcanic chain of the Sunda Islands, including Sumatra and Java. The island of Borneo in the centre of these chains, is considered to be free from the effects of modern volcanic action.

The above are the most clearly defined volcanic chains on the grandest scale, but there are several which are less evident, and not so extensive. Of these, the most re-markable is the group of the south of Italy, Sicily, and the Lipari Islands, which are probably ranged along branching fissure lines partially closed.* It is possible

---

* A map, showing the arrangement of the vents of the Lipari Islands is given by Judd, *Volcanoes*, p. 193.

that this group may be connected by a deep fissure running along the Italian peninsula,* and northwards through Central France, the north-east of Ireland, and the Inner Hebrides into Iceland, where volcanic action still continues.

The region lying to the east of the Jordan-Arabah valley, and extending from the base of Hermon into the centre of the great Arabian Desert, appears to have been also the seat of volcanic action on a grand scale during the Pliocene and succeeding periods. The volcanoes of the Jaulân and Haurân retain their form with but little modification since they became extinct, and at intervals extensive sheets of basaltic lava may be traced to considerable distances from their vents of eruption. Similar volcanic sheets are found amongst the hills of Moab, as shown by Tristram and Lartet ; and a more recent traveller, Mr. C. M. Doughty, has described numerous extinct volcanic craters and lava-floes in parts of central Arabia, which hitherto have been a *terra incognita* as far as regards their geological structure. The general resemblance of these Arabian volcanoes to those of the Jaulân is unquestionable ; and we may safely conclude that they were both in active operation at the same recent geological period, and formed a continuous chain of more than 600 miles from north to south.†

---

* The Italian Riviera, recently the scene of a disastrous earthquake, would be on this line.

† Doughty, *Arabia Deserta*, (1888).

Numerous volcanic islands rise from the deep waters of the Atlantic, Pacific and Indian Oceans, such as those of the Azores, Canary, Cape de Verde in the Atlantic, the Sandwich, Society and Friendly Islands in the Pacific, and Bourbon in the Indian. It is not improbable that some of the coral Atolls of the Pacific are built upon the summits of submerged volcanic craters; and, were the bed of the ocean to be laid dry, these volcanic islands would appear like stupendous pyramidal mountains planted on a nearly level floor, and rising to elevations of several thousands of feet.*

F.—Geysers.

Amongst the secondary results of volcanic action, is the formation of Geysers, which are often found in those districts where volcanic action is dying out, or has become dormant, such as in parts of Iceland, New Zealand, and the Yellowstone District of Western America. They may generally be described as inter-mittent eruptions of water, at a temperature little removed from that of boiling point, which is from time to time blown out of a central funnel, opening downwards into the ground. These eruptions are often accompanied by a loud subterranean noise and the evolution of steam, which must be considered as the motive power at each explosion.

---

* They are in fact supported in position mainly by the dense waters of the ocean.

Other forms of moribund volcanicity are to be found in solfataras, fumaroles, mud-volcanoes, and boiling springs; but space does not allow of detailed description of these phenomena.

G.—Causes of Volcanic Action.

The causes assigned for volcanic action by various authors may be classed under three heads :—

(1.) Chemical,
(2.) Mechanical, and
(3.) Secular contraction of the Earth's Crust.

(1.) Of the first of these explanations, Daubeny is the chief exponent.* Briefly stated, he considers the heat generated during volcanic action is due to air, water, and muriatic acid, which find their way into the interior through fissures in the crust, and, acting chemically on the metallic constituents of which the crust is formed, give rise to volcanic eruptions.

(2.) According to the mechanical theory, expounded by Lyell, the internal heat is assumed; and water, either mixed with molten rock, or finding its way downwards through fissures, and coming in contact with heated or

---

* Daubeny, *Active and Extinct Volcanoes* (Edition 1848).

molten matter, is converted into steam, and is the direct
cause of volcanic eruptions.*   This view has been very
generally adopted by geologists, but labours under the
difficulty of supposing that water can find its way down-
wards amongst highly heated matter, where it would be
immediately converted into steam, notwithstanding that
the boiling point would be raised by the increased pres-
sure due to depth.†

(3.)   The explanation under the third head has its
chief exponent in Mr. Mallet, who, following Von Buch,
supposes that in consequence of the secular cooling of
the earth's crust, lateral crushing takes place along lines
of fracture or faulting.   From time to time, the resistance
of the crust gives way to the tangential forces, resulting
in earthquake shocks, together with the development of
heat along the lines of fracture, and the melting of rock
into lava.   Meanwhile, water, finding its way down-
wards, gives rise to explosive energy, the evolution of
steam, and the extrusion of lava from the pre-existing
vents of eruption.·

This view is not incompatible with that of the most
recent writer on the subject, Professor Prestwich, who,
appealing to the fissures of eruption of lava in the Sierra
Nevada and Western America, considers that the evo-

---

* Lyell, *Principles of Geology*, Vol. II., pp. 198, 242-4.   (Edit. 1872.)
† This difficulty was recognised by Lyell, who, however, did not consider it
insuperable.

lution of steam is only a secondary cause of volcanic action. Thus, molten lava, ascending through the throat of a volcano, comes in contact with water contained in the strata, or in the ashes and scoriæ of the volcanic mountain, and is thus converted into steam. The prime motive power of volcanic action he considers to be the secular cooling and contraction of the crust.[*] The fact that so many active volcanoes are situated in proximity to the ocean is not necessarily a proof that the access of oceanic waters is a direct cause of volcanic action, as the position of the coast lines may have been, to some extent, pre-determined by the great lines of fracture and thrust, along which lines of volcanic eruption have been developed.[†] The views of Professor Prestwich are those which appear most consistent with observation and what we know of the internal condition of our globe.[‡]

---

[*] Prestwich, *On the Agency of Water in Volcanic Eruptions*, *Proc. Roy. Soc* 1886, p. 171.

[†] This point is ably urged by Judd, *Volcanoes, loc. cit.*, p. 239, &c.

[‡] Cordier has calculated that a radial contraction so minute and imperceptible as one millemètre (0·0397 inch) would suffice to supply matter for five hundred of the greatest known volcanic eruptions. Prestwich, *Geology*, Vol. I., p. 216.

CHAPTER III.

EARTHQUAKES.

A.—Connection of Volcanic Eruptions and Earthquake Shocks.—Destruction of Herculanæum and Pompeii.

The connection of tremors and shocks passing through the crust with volcanic outbursts has long been observed and acknowledged; but, at the same time, it is certain that earthquakes take place in regions where there is an entire absence of volcanic phenomena, or from which they have long since passed away. Of the connection above referred to, the history of Vesuvius affords us numerous examples. Down to the commencement of the Christian era the subterranean fires of this mountain were dormant.* The summit formed a plain of rough slag and cinders, while the sides were clothed with vines, olives, and fertile meadows. But this epoch of tran-

---

* That is, within the historic period; the original crater before the Christian era is called Somma.

quility was brought to a sudden and calamitous close, when, in A.D. 63, repeated earthquake shocks disturbed the Campania, and shattered the cities of Herculanæum and Pompeii, which were built, the one at the base, the other on the side of the mountain. Another earthquake of scarcely less intensity, shook the whole region around the Bay of Naples on the 24th August, 79, and was followed by the first recorded eruption of Vesuvius, when the summit of the mountain was blown off, a new cone of eruption was formed, to which the name Vesuvius is restricted, and from which clouds of smoke, ashes, and lapilli were sent forth, rendering the heavens dark as midnight, and adding to the terror of the affrighted inhabitants, who fled in all directions from the scene of the disaster. Since then Vesuvius has been, from time to time, the scene of eruptions, accompanied or preceded by earthquake shocks.

B.—NON-VOLCANIC EARTHQUAKE REGIONS.

On the other hand we have only to cast our eyes over a map of the Globe showing the regions liable to earthquakes, to see that there are extensive regions in North America, the South of Europe and Central Asia which are frequently visited by earthquake shocks, but from which volcanic action has long since passed away. Amongst such may specially be mentioned southern Spain, the east shore of the Adriatic, Syria, and the Jordan Valley, parts

of Asia Minor and of Northern India.* The recent terrific
earthquake of the Riviera in northern Italy, which took
place on the 23rd February, 1887, at 5.30 a.m. (local
time), travelled from east to west through a region
destitute of volcanoes. This case also affords an instance
of the vast distance to which earthquake-waves are capa-
ble of being transmitted—as the vibrations appear to
have extended across the Atlantic, and sensibly affected
the seismoscope in the Government Signal Office at Wash-
ington, at a moment which, when compared with the
time in the Riviera, and, with the local times, indicated
a velocity of about five hundred miles an hour.† It is
not improbable that some of the greater shocks have
been felt throughout the whole circumference of the
globe.

C.—Nature of Earthquake Shocks.

Earthquakes appear to have their origin either in a
sudden crush of the crust, owing to contraction along
great lines of fracture, or in powerful efforts of steam
or elastic gases to effect an escape from the interior,

---

* The Great Earthquake of Cachar, which occurred on the 10th January, 1869,
in northern India, has been described by the late Dr. Oldham and his son, from
observations on the spot. The catalogue of Earthquakes prepared by Professor
O'Reilly, and published in the *Trans. Roy. Irish Academy*, show many earthquake
centres from which volcanic vents, either active or extinct, are absent.

† Mr. W. H. M. Christie states that the shock was felt at Greenwich Observa-
tory, at 5.38 a.m., by the sudden vibration of the declination and horizontal force
magnets.—*Nature*, 17th March; and at Washington, at 7.50 a.m.—*The Times*
telegram.

owing to contact with molten matter. It is not difficult to understand how, in the case of a volcano, long dormant, but about to enter upon a period of activity, the molten matter ascending through the throat of a funnel may come in contact with strata charged with water, or even with old lava and ashes similarly charged; steam would then be generated under high pressure, and would
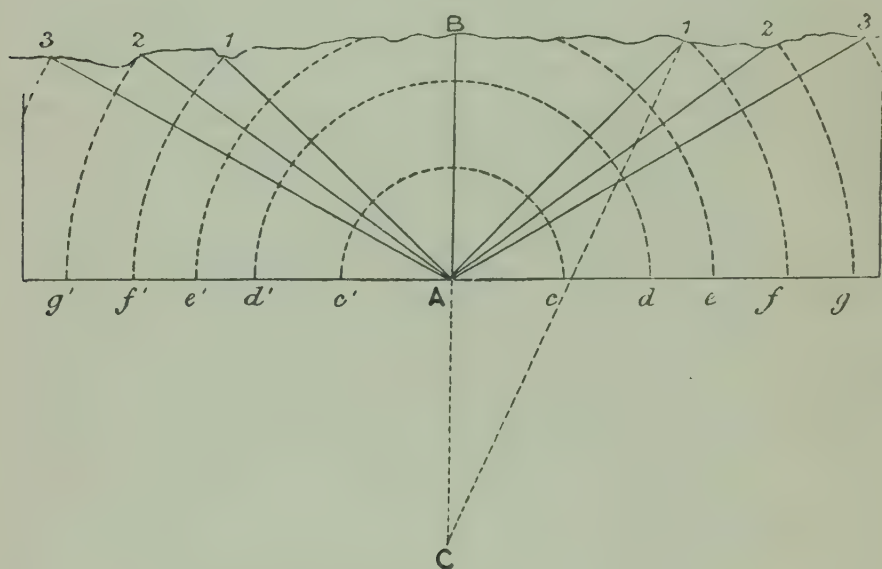
Fig. 5.—DIAGRAM TO SHOW THE MODE IN WHICH AN EARTH-QUAKE-WAVE IS TRANSMITTED FROM A SUBTERRANEAN FOCUS OF DISTURBANCE SUCH AS AT A.—A. Focus of Earthquake. B. Seismic Vertical, or point where shock first reaches surface. C. Supposed focus of greater depth. Here line c. 1, representing angle of emergence, is steeper than the line A. 1. c, c', d, d', &c., section of spherical shells showing how the wave is propagated in all directions from the centre of disturbance A. 1, 1', 2, 2' &c., co-seismic points—points on the surface reached simultaneously by the Earthquake-wave.

result in one or more shocks within the crust. In some such manner may we account for the shocks which preceded the first recorded eruption of Vesuvius. These shocks originate vibratory waves in the crust, which are propagated in various directions from the seat or focus of disturbance in the manner illustrated and described by Mr. Hopkins. This mathematician has shown, that the earthquake-wave, when it passes through rocks differing in density and elasticity, changes in some degree, not only its velocity, but its direction ; being both refracted and reflected in a manner analogous to that of light when it passes from one medium to another of different density. When a shock traverses the crust through a thickness of several miles it will encounter a great variety of rocks, as well as fissures and faults, by which the course of the vibratory movement will be more or less interfered with and diverted.*

* Space does not admit of further discussion of this subject here, and the reader is referred to Mr. Hopkins' *Report on Theories of Elevation and Earthquakes*, Rep. Brit. Assoc., 1847, p. 33. Mr. R. Mallet *On the Dynamics of Earthquakes*, Trans. Roy. Irish Acad., vol. xxi. Lyell's *Principles of Geology*, 11th edit., p. 136. Prof. O'Reilly's *Catalogues of Earthquakes*, Trans. Roy. Irish Acad., vol. xxviii., (1881 and 1886).

PART III.

PHYSICAL FEATURES OF THE GLOBE.

CHAPTER I.

VARIETIES OF SURFACE FEATURES.

A.—General Statement regarding their Origin.

THE physical features of the surface of the globe are
the ultimate result of the combined action of in-
ternal forces of movement and external agents of erosion
on the solid matter of which the crust is formed. The
mountains, plains, hills and valleys, oceans and lakes,
are all due to such agencies, amongst which the forces
of elevation and of erosion by rain, river, and sea action
are the most powerful. It should always be borne in
mind by the student of nature that the features of the
landscape are altogether different from what they were in
the earliest epochs of the history of our globe; and we

might go so far as to say that every spot of existing land
has, at one time or other, formed part of the bed of the
ocean, some portions having been repeatedly in this con-
dition,* while, on the other hand, it may be affirmed with
equal certainty, that very large areas of the existing
oceans have, at one time or other, been in the con-
dition of emergent lands—the North Atlantic being one
of these.†

The manner in which the above physical changes have
been brought about, and the special epochs of each, be-
long to that branch of scientific research known as
Physical Geology, upon which it would be out of place
to enter here. We must, therefore, confine our attention
to the features as they are at present represented on the
surface of our globe.‡

B.—Mountains: their Structure and mode of Formation.

The structure and mode of formation of mountains is

---

* The converse proposition that every spot of the ocean has once been land
does not necessarily follow, because of the greater extent and greater mean depth
of the submerged over the emergent areas.

† For the evidence of this statement the reader is referred to the author's
paper on *The Geological Age of the North Atlantic Ocean; Scientific Trans. Roy.
Dublin Society*, Vol. III. (1885); and *Contributions to the Physical History of the
British Isles* (London, 1882), p. 23.

‡ Those who wish to pursue this subject further may consult Elie de Beaumont's
Systemes de Montagnes, Paris, 1852; Mr. W. Hopkins' *Anniversary Address, Geol.
Soc. Lond.* 1853; Prestwich's *Geology*, Vol. I., p. 285; Geikie's *Text-book of
Geology*.

a subject so vast and complicated that it would be impossible to enter upon it in a treatise like the present with any prospect of successful treatment. In addition to this it is to be recollected that as the mountain ranges of our globe descend to the present day from distant geological periods, their structure and formation belong rather to the domain of physical geology than that of physical geography. A very few leading ideas may, however, here be advanced. Neglecting those of specially volcanic origin to which we have already referred, nearly all mountain ranges may be regarded as coming under two classes :—

(1.) Those which, having originally been in the condition of elevated plains or table-lands, have been channelled and furrowed by rain and river action, and thus sculptured into various forms of mountain heights with intersecting valleys. The hilly tract of Central Wales, or the plateau of the Cotteswold Hills, or the Carboniferous ranges of the North-West of Ireland, offer familiar examples of this kind. The original floor out of which, upon its elevation, the hills and valleys have been eroded, may have consisted either of horizontal or contorted strata, worn down by marine action, and thus reduced to a nearly level surface. Such surfaces have been designated by Sir A. Ramsay " planes of marine denudation."

(2.) The second class consists, generally, of masses arranged more or less along parallel lines, and often with a

central ridge. These ridges are the result of lateral thrust, by which the strata are flexured along axes perpendicular to the direction of pressure. The Alps, Pyrenees, and Himalayas belong to this class. Along with the flexuring of the strata, there is often direct upheaval along lines of fault or fracture, accompanied by the protrusion of igneous rocks ; while the valleys have been eroded by rain and river action, generally along lines of faulting, or along softer strata, above which the harder beds rise in ridges or escarpments. Such mountain ranges have sometimes undergone repeated upheaval and depression during succeeding geological periods. Where river valleys cut through ridges or escarpments, we have to refer back to very old systems of drainage to account for such remarkable cases, of which examples occur in the south of England, and nearly all mountainous regions of the globe. In the former case it will be observed that the streams which have their sources in the high ground formed of " Kentish Rag " and the " Hastings Sands," forming the central Wealden area of Kent and Sussex, flow northwards into the Thames below London, and into the English Channel, crossing in their course the Chalk-ridges called the " North and South Downs," instead of finding their way eastwards into the sea along the valleys formed of the " Weald Clay." The explanation of this is to be found in the fact that these river channels were formed during the progress of the denudation of the chalk and tertiary strata from off the Wealden area.

CHAPTER II.

THE OCEANS.

A.—Their Extent and Mean Depths.

The oceans date, in some cases, from very early geological periods. Their waters, with those of the inland seas, occupy more than twice the extent of the surface of the land, amounting to 146 millions of square miles.

The more exact proportions are as follows :—

    Land surface . . . 51,000,000 square miles.
    Water surface . . . 146,000,000   ,,   ,,

The mean depths of the oceans may be taken as follows :*—

---

* Haughton's *Lectures on Physical Geography*, 1880.

	Feet.
North Atlantic (central portion) . . .	14,053
South ,, ...	13,077
North Pacific	15,500
South ,, ...	12,987
South Indian	10,610

The mean depth of the ocean taken as a whole has been estimated by Dr. Carpenter at 13,000 feet, while the mean level of the land above the ocean is only about 1000 feet; so that the mean depth of the former is thirteen times the height of the latter.* As regards the relative mass of emergent land and of oceanic water, we obtain the result by multiplying the mean heights and depths by their respective areas, which shows an enormous preponderance in the mass of submerged land.

B.—Ingredients of Ocean Waters.

The waters of the ocean are intensely saline, perfectly clear when at a distance from land or the mouth of a river, and have a high specific gravity, owing to which they are more buoyant than those of lakes or rivers. The chief saline ingredients are chlorides of sodium and magnesium, sulphates of magnesia and lime, silica, and

---

* Carpenter, *Land and Sea*, Proc. Roy. Inst. Gt. Brit., June, 1880. Haughton's estimates differ a little from those of Carpenter, as he takes the mean depth of the ocean at something over 10,000 feet, *loc. cit.*, p. 44. Dr. Murray makes the mean height of land 2,230 feet, and mean depth of the ocean 12,480 feet.

traces of bromides and iodides. Carbonic and phosphoric acids, carbonates of lime, and magnesia are also present, together with the silica, and are seized upon and converted into the shells and skeletons of the numerous animals and plants which abound throughout the oceanic waters even to the profoundest depths.

The proportions of dissolved ingredients, however, vary somewhat according to the conditions of locality. If we take the average proportion to be 34·4 grammes per litre,* that of the Mediterranean varies from 36 to 40 grms., and of the Baltic only from 5 to 18 grms. per litre; these being extreme variations due to exceptional causes. As regards the Mediterranean it is known that the evaporation is greater than the supply from both rivers and the Atlantic through the Straits of Gibraltar; while, in the case of the Baltic, it is almost shut out from physical connection with the waters of the outer ocean, and the supply from rivers and rainfall is so great as to reduce the salinity much below the average amount. A curious result of this brackish condition of the Baltic waters is, that the molluscs of that sea are more or less dwarfed in size, as compared with their representatives in the adjoining Atlantic.

C.—Geodetic Level of Ocean Surface.

If the world was formed of water, of equal depth

---

* Forchhammer, *Phil. Trans.*, Vol. 145

throughout, resting on a floor of uniform density, the surface would be that of an ellipsoid of revolution, and would be regarded as presenting a true geodetic level. As a matter of fact, it is generally so regarded; and where land occurs in the existing globe, the mean geodetic surface is considered to be that of the ocean continued into the land. But recent investigations have tended to show that the ocean surface varies considerably from the mean level, owing to the attraction of adjoining lands. Professor Stokes has shown that the force of gravity must be greater in mid-oceanic islands than on continental stations,[*] that is at the sea margin and in similar parallels of latitude, and this conclusion corresponds with the results of observations on the length of the second's pendulum all over the globe. Suess[†] and Fischer[‡] have arrived at a formula, according to which, the difference in the level of the ocean surface at two such stations above or below the mean ellipsoidal level is found in *mètres*, by multiplying the defect or the excess, respectively, in the number of daily oscillations of the second's pendulum above or below the calculated number for the latitude of the place in question, by 122; which would give very unexpected results in some cases.

The attraction of the submerged land, which, as in the

---

[*] Stokes, *Cambridge Phil. Trans.*, vol. viii. pp. 672 *et seq.*

[†] Suess *Das Antlitz der Erde* (1887).

[‡] Fischer *Untersuchungen über die Gestalt der Erde* (1886).

case of the coast of S. America, descends to depths of 14,000 to 15,000 feet, is much greater than that of the emergent masses. That the waters of the ocean are to a greater or less extent drawn up all along the shores of the continents, to a level above the mean geodetic surface, can scarcely admit of a doubt. On the other hand, the deeper oceanic depressions will produce a corresponding depression in the ocean surface, so that this surface in some slight degree partakes of the irregularities of the bed beneath.*

D.—Depths of the Ocean, and Nature of its Bed. Oceanic Islands.

The mean depth of the oceans, as shown above, may be taken at about 13,000 feet, or 2,166 fathoms; but deep-sea soundings have shown that the Atlantic and Pacific Oceans descend to much greater depths. Thus the soundings made across the Atlantic basin from Valentia Island to Trinity Bay, Newfoundland, show that the bottom descends to a depth of 14,616 feet, at a distance of 300 miles west of Cape Clear. In the S. Pacific, a depth of 15,900 feet was sounded by the officers of the "Challenger" Expedition, between the Fiji Islands and Torres Straits; and still greater depths have

---

* Objection has been raised to the above views from the fact that the Himalayas indicate by the plumb-line a deficiency of attraction due to the mass, as shown by Pratt, Clarke and Fisher; the subject is too complex for discussion here.

been reached in both oceans. Notwithstanding these exceptional depressions, the general form of the oceanic bed appears to be that of a nearly flat, or gently undulating, surface, from which arise, solitary or in groups, volcanic islands, with steep or precipitous sides. The island of Tristan da Cunha in the S. Atlantic, rises abruptly from a depth of 12,150 feet;* St. Helena, Trinidad, Ascension, and St. Paul's Islands from still greater depths ; and if the sea were laid dry, these islands would look like gigantic pyramidal mountains rising from a plain.

E.—THE ATLANTIC PLATEAU.

Following the course of the centre of the ocean, a narrow plateau, called the " Dolphin Ridge," stretches southwards from opposite the extremity of Greenland into the Antarctic Ocean by Tristan da Cunha. This plateau has a depth of 1,000 to 2,000 fathoms, and is bounded on either side by wider tracts of depths over 2,000 fathoms, which stretch on either hand to within comparatively short distances of the land.

F.—MARGIN OF THE OCEAN.

The soundings which have been carried out over large tracts of the ocean, from the margin of the land, have revealed

---

* Haughton, *loc. cit.*, p. 45.

the remarkable fact, that the continental lands descend at a more or less uniform slope into very deep water, and this having once been attained, very little change takes place in the depth of the oceanic bed over large areas, except around oceanic islands. This somewhat uniform descent into deep water is specially illustrated in the case of the western coast of the two Americas, along which the land appears to descend to a depth of 2,000 fathoms, at a distance of about 100 English miles all along the coast of Mexico, Peru, Bolivia, and Chili, to lat. 35 degrees S., while the depths of the ocean beyond gradually vary from 2,500 to 3,000 fathoms.* The descent of the submerged land margin into deep water is not, however, as rapid as is generally supposed, being at the rate of 1 in 44 (or about 1½ degrees) to 1 in 20 (or about 3 degrees).

If we take as guides the soundings of the Admiralty charts, which only extend to depths of about 500 to 600 fathoms, we obtain an idea of the rate of descent into deep water. From one of these charts of the coast of Peru, between lat. 18° 50′ and 20° S., we obtain soundings to a depth of 500 fathoms, which show an average slope of about 1 in 20, or about 3 degrees.† What has been said in reference to the coast of America applies to a greater or lesser extent to those of Africa, Asia and Europe.

---

* Isobathic lines of Physical Map in the *Scientific Results of the " Challenger " Expedition*, Vol. i.

† This slope is really not so rapid as might be supposed from an inspection of the isobathic lines on a physical map, owing to the comparison of the horizontal and vertical distances.

G.—Composition of the Ocean-Bed.

Soundings and dredgings have also made us acquainted with the nature of the bed over almost the whole accessible tracts of the ocean, and have brought to light the remarkable fact that the remains of animals and plants have contributed far more than inorganic bodies to its formation. The general results may be stated as follows :—After passing beyond a depth of 200 to 300 fathoms, and also beyond the influence of large rivers entering the sea, the ocean-bed becomes remarkably uniform in composition, being composed mainly of calcareous foraminiferal marl, similar to the "ooze" of the mid-Atlantic. In some parts of the southern oceans the calcareous marl is replaced by silicious matter, made up of remains of sponges and radiolarians, or else of diatomaceæ. In the neighbourhood of volcanic islands, fragments of pumice, generally rounded, as well as particles of volcanic dust, have been dredged, which, owing to their light specific gravity, may have been carried to great distances from their volcanic sources. But, perhaps, the most extraordinary of all abyssal bodies recovered are the round grains of " cosmic dust," that is, portions of the dust of meteorites, which have been brought up from the ocean-beds at distances far remote from land, and where, consequently, deposition of matter

G

goes on with extreme slowness. These have been brought up from depths of over 3,000 fathoms in the Pacific Ocean, and are found to consist of rounded grains of magnetite or bronzite. Along with these deep sea deposits are whale bones, sharks' teeth and bones, often coated with peroxide of manganese, as well as other remains of marine animals.* In the Indian and S. Atlantic Oceans, the calcareous ooze often gives place at depths of 2,200 fathoms to " grey clay," and this again to " red clay " at 2,400 fathoms, this latter forming the floor over large tracts. The red clay was once supposed to be the " residual ash " left by the casts of foraminiferal shells after the calcareous portion had been dissolved away; but more recent observations go to show that it is really decomposed matter derived from volcanic eruptions.

On approaching the continental lands, the materials composing the ocean-bed become more inorganic and fragmental, and ultimately pass into sand and gravel, mixed with shells and other marine forms, as we find along our coasts and bays. Toward the Arctic and Ant-arctic circles, a material change takes place owing to the presence of mud, stones, and fragments of rock which have been strewn over the ocean-bed by bergs and floes of ice when floating in the waters and undergoing dissolution. The material thus formed, must, we may suppose, be

---

* Murray and Renard, *Proc. Roy. Soc.*, Edin., 1884.

similar to a portion of the formation belonging to the glacial period, known as boulder clay.*

H.—CONTRAST BETWEEN THE FORM OF THE OCEAN-BED AND THE SURFACE OF THE LAND.

The form of the ocean-bed, as revealed by deep sea soundings, contrasts remarkably with that of the land surfaces adjoining. The former presents to our imagination the aspect of an immense plain, slightly sloping in various directions, and only occasionally diversified by the uprise of oceanic islands, either in groups or singly; on the other hand, the land surface is highly diversified by ridges and furrows, by plains and mountains, and especially by river-valleys, features which are absent from the submerged areas. How are we to account for these highly contrasted forms of surface? The question is one which would require considerable space to answer fully, and may only be touched upon here. Briefly stated, then, the floor of the ocean possesses the character due to sedimentation and accumulation of organic matter deposited slowly, and under the influence of slow current action; while the surface of the land is such as results from aqueous erosion operating on various rocks and varie-

* This material differs from the Till, or Lower Boulder clay, which is of land-ice formation, in being stratified.

ties of strata.   The tendency of the former agencies is to
fill up inequalities, and thus produce extensive level
surfaces; that of the latter, to give rise to endless inequali-
ties and variations in the forms and features of the
landscape.

CHAPTER III.

HOW THE OCEANIC WATERS BECAME SALT.

A.—Original Formation of the Ocean Basins.

We are so accustomed to the saltness of sea-water that few persons ask themselves the question, why it should be salt any more than the waters of lakes? Yet, if we reflect that originally the waters of the sea were gathered together into the hollows formed over the earth's crust during its consolidation, in consequence of the condensation of the vapours which once surrounded a highly-heated globe, we are obliged to infer that these waters were originally fresh, and that the process of salinification is one which has taken place subsequently to the original formation of the great seas. The question, therefore, remains, by what process has the water become so highly impregnated with saline matters in solution as to become intensely " salt " to the taste, while waters of lakes communicating with the same ocean are so slightly saline as to be considered " fresh " ?

B.—Salt Lakes.

In approaching this question we cannot forget that
there are certain inland lakes, such as those of the
Dead Sea in Palestine, the Sea of Aral, the Lakes of Van
and Urumiah, the great Salt Lake of Utah, and others,
the waters of which are more or less saline; and
when we come to enquire what peculiarity of physical
conditions characterises these lakes, we find that it is one
which they all possess in common, namely, that they are
lakes without an outlet, and that the waters which they
receive from the rain and streams pass off into the air by
evaporation. Now the ocean may be regarded as a vast
sea without an outlet, and hence we have a clue to the
determination of the problem regarding the cause of
salinity in its waters.*

C.—Saline and other Ingredients in Sea-Water.

The chief soluble ingredients of sea-water have already
been enumerated. The proportions of these materials
vary somewhat in different parts of the ocean, and at
different depths, but 28 or 29 grammes per litre may be

---

* Halley long ago showed that the saltness of the Sea is due to the salts brought
down by rivers and left there by evaporation. (*Phil. Trans.*. No. 344). Bischof
concurs in this view, *Chemical Geology*, Vol. i., p. 110, (*Trans.*)

taken as an average. Now these ingredients in sea-water are exactly those which are found in solution in the waters of rivers in small quantity, with the exception perhaps of bromides and iodides, which may occur only in such small proportions at to escape detection.* They are constantly being taken up from the rocks and soil, then carried down and poured into the ocean from the rivers and springs; and, as in the process of evaporation by which these waters are carried back to the land, the soluble ingredients are left behind, the conclusion is inevitable, that the waters of the ocean have a tendency as time goes on to become more and more saline. This tendency towards saturation does not apply, however, to the carbonates and to silica, as they are used up by the various living forms, both animal and vegetable, inhabiting the waters, for the construction of their shells and skeletons.

As bearing on this subject, it is interesting to observe that the waters of the Mediterranean are slightly more saline than those of the outer ocean. This is in consequence of the enormous evaporation which takes place over its surface owing to the dry winds of Africa and Asia, which the large rivers, such as the Nile and Danube, directly or otherwise finding their way into it, fail to

---

* Bromine occurs in the waters of the Dead Sea, but has not been noticed in the waters of the Jordan; this is only in consequence of the restricted quantity of water subjected to analysis, Lartet, *La Mer Morte, Geologie,* (1880). On the subject of the occurrence of bromine and iodine in small quantities in rocks and waters, see the observations of Bischof, *Chem. and Phys. Geol.,* vol. i., p. 348.

supply. In consequence of this, the Atlantic pours its waters into the Mediterranean through the Straits of Gibraltar, with the result of producing an increase in the saltness of its waters.*

D.—The Dead Sea of Palestine.

Still more remarkable than the case of the Mediterranean is that of the Dead Sea (otherwise called "The Salt Sea" and "Bahr Lût") of Palestine. The position of this inland lake is unique amongst all other lakes of the world, as the surface of its waters lies 1,290 feet below that of the Mediterranean; and its bed descends to a nearly equal depth below the surface. Its length from north to south is 47 miles, and its waters are so intensely saline that no animal can remain in them alive, and the fishes that enter the head of the lake from the Jordan soon perish. The Dead Sea once occupied an area at least three times larger than at present, and it is

---

* While the views above stated regarding the cause of salinity of the ocean waters are those which appear most in harmony with fact and observation, it is proper to observe that some authors refer the salinity of the ocean water more directly to chemical reactions which took place at a very early period of the earth's history. The chief exponent of this view is Dr. T. Sterry Hunt, who finds that, on comparing the saline matters locked up (as he supposes) from the period of the ancient Palæozoic seas in the strata with those of the present ocean, only one half of the chlorine is combined with sodium, the remainder existing as chlorides of calcium and magnesium; hence he infers that these latter chlorides have been replaced to a large degree by chloride of sodium, through the intervention of carbonate of soda in the waters of the present ocean. Soda, as he points out, is pre-eminently the soluble alkali; hence its abundance in the waters of the ocean, and most saline and alkaline waters; while potash, which is less soluble, predominates in the felspars and solid matters of the earth's crust. *Chemical and Geological Essays*, 2nd Edit., p. 11.

probable that its waters have not been physically con-
nected with the outer ocean since the Pliocene Epoch.
The principal ingredients in its waters are the chlorides
of calcium, magnesium, sodium, and potassium ; and, in
the smaller proportions, of sulphates and bromides of the
same substances.* As the waters of this lake are carried
off by evaporation as fast as they are delivered by the
Jordan and other streams, it follows that the saline in-
gredients have been derived from the streams themselves,
and these in their turn from the rocks and strata amongst
which they flow, and have their sources. Thus the
history of the increasing salinity of the Dead Sea may be
considered an epitome of that of the outer ocean itself.

E.—THE CASPIAN SEA.

This great inland sea seems to offer a remarkable excep-
tion to the rule which regulates the saltness of lakes
without an outlet. It has been supposed by Hommaire-
Dehel,† and others more recently, that the waters of the
Caspian formerly flowed into the Black Sea, and that
the lakes Aral, Caspian, Azov, and the Black Sea formed
one great chain communicating with the Mediterranean.
That the sea of Aral and the Caspian were connected is

* For fuller details see *Physical Geology of Arabia Petræa and Western Pales-
tine—Mem. Palestine Exploration Society*, pp. 15, 118, &c.
 † *Comptes rendus*, 1843, No. 15.

beyond question, as the old bed of the Oxus can be traced from sea to sea; but if the Caspian had been once connected with the Black Sea, its waters ought now to be more saline than those of the latter, which is so far from being the case, that the waters of the Caspian contain only one-fourth of dissolved constituents of those of the Black Sea. The surface of the Caspian is also 86.5 feet lower than that of the Black Sea; so that, if once united, a column of water has been evaporated off the surface of the Caspian, owing to which its salinity ought to have been proportionately increased. Hence, Bischof concludes * that these large seas can never have been physically connected; notwithstanding the fact, shown by the old alluvial tracts with shells identical with those now living, that the waters of the Caspian once had a much wider range than at present. It is not easy to see how this conclusion can be invalidated.

At the same time it might fairly be argued, that the fact of the deficiency of salinity (supposing this to be fully determined) can only be accounted for by the supposition that the waters of the Caspian had, till recently, a physical connection with those of the Black Sea, with a current into the latter, and that owing to the excess of evaporation over supply in more recent times, the surface had fallen below the level necessary for maintaining this connection. It is known, however, that in one part of the

* *Chem. and Phys. Geol.*, vol. i., p. 90.

Caspian (Kara Bucharz), the waters are so saline that beds of rock salt are in course of formation by a process of evaporation.*

F.—The Substances carried by Rivers into the Sea.

From the above considerations we arrive at the following general conclusions regarding the substances which are carried down by rivers into the ocean. As regards the materials held in mechanical suspension, such as clay, sand and pebbles, these are deposited along the borders of the ocean and at the mouths of the rivers, and are carried to greater or lesser distances from the land by the currents which pervade the waters. The carbonates of lime and magnesia, together with the silica in solution, are seized upon by animal and vegetable organisms, and being used up in the construction of the shells and skeletons of these forms are thus converted into solid matters ; while lastly, the chlorides of sodium and magnesium, together with the sulphates of magnesia and lime remain for the most part dissolved, and tend to augment the saltness of the ocean'c waters. Owing, however, to the vastness of the volume of these waters, the process is excessively slow, and except through long geological periods, probably almost inappreciable.

---

* Numerous salt-lakes are distributed over the great plains lying to the north of the Lake of Aral, and other parts of Central Asia ; all characterized by the absence of an outlet.

G.—Lakes without an Outlet, or "Closed Lakes."

Having already indicated the cause of the salinity of these lakes, to which there are but few exceptions, it will be sufficient to give the results of analyses of some of the more important examples taken from various parts of the world. All such lakes are more or less saline; but instances occur in the great Lahontan basin in Nevada where lakes have become fresh by dessication in connection with the deposition of mineral matter; the process here going on at the present day throws much light on the formation of saliferous deposits.*

H.—Analyses of Waters of Closed Lakes.

Dissolved ingredients in 1000 parts.

Aral Sea, Asia†	10·841
Albert Lake, Oregon‡	27·357
Caspian Sea‖, 2° W.S.W. of Pischina, 15 feet deep	6·294

---

* I. C. Russell's *Geological History of Lake Lahontan, U. S. Geol. Survey* (1885) page 224.

  † *Fourth Annual Rep. U.S. Geol. Survey*, p. 454.

  ‡ Göbel, *Pogg. Annal. Ergänz.* b. i., p. 187.

  ‖ Terrell and Lartet, *Geol. Explor. Dead Sea*, p. 278.

Dead Sea[*], near Ras Feschkah, 393 feet deep .   245·732

    ,,   ,,   ,,   656   ,,   ,,   .   251·103

Elton Lake, Russia[†]   .   .   .   . 255·6—264·980

Great Salt Lake, America[‡]   .   .   .   222·820

Soda Lake, Ragtown, Nevada[||]   .   .   .   113·644

Oroomiah (Urumiah), Persia[§]   .   .   .   205·500

Pyramid Lake, Nevada[¶]   .   .   .   .   3·486

Sevier Lake, Utah[**]   .   .   .   .   .   86·403

Van Lake[††]   .   .   .   .   22·600

---

[*] Erdman and H. Rose, *Bischof Chem. Geol.*, vol. i., p. 404.

[†] L. D. Gale.

[‡] Stambury, *Great Salt Lake*, p. 419. *U.S. Geol. Survey*, Vol. xi., p. 70.

[||] Bischof, *Loc. Cit.*, vol. 1., p. 401.

[§] *U.S. Geol. Surv.*, vol. iii.

[¶] Lakes of the Lahontan Basin. *Monog. U.S. Geol Survey,*

[**] De Chancourtois, *Bischof*, vol i., p. 94.

[††] Roth., *Chem. Geol.* p. 465.

CHAPTER IV.

CORAL ISLANDS AND REEFS.

A.—Distribution and Nature of Coral Reefs.

Coralline limestones are widely distributed throughout certain parts of the ocean at the present day, and are of frequent occurrence amongst strata of past geological times.

It has long been observed by naturalists that coral reefs and islands are restricted to the warmer parts of the ocean, and, therefore, absent from others; and their conditions of existence have been studied and very generally recognized.* Their appearance in the central portions of the

---

The chief authorities are C. Darwin, *Structure and Distribution of Coral Reefs* (1874); Ehrenberg, *Poggend. Annal*, Vol. 41; Jukes, *Voyage of H. M. S. Fly* (1842-46); Haeckel, *Journey to Ceylon*; Dr. J. Murray, of the *Challenger* Expedition, *Proc. Roy. Soc. Edinb.* 1880; Lyell, *Principles of Geology*, Vol. ii. (Edit. 1872).

Pacific and Indian Seas, rising but slightly above the surface, far remote from land, and exposed to all the fury of the breakers, has produced astonishment in the minds of beholders, and a strong desire to investigate their structure and conditions of environment.

These remarkable structures consist of masses of calcareous rock, forming the abode and skeletons of the coral animals or polyps by whose agency they are built up, and are distributed throughout the Pacific, Indian, and Central Atlantic Oceans, where the waters are clear and free from sediment, and where the temperature never falls below 66 degrees Fahr. These two conditions, namely, those of purity and warmth, are essential to the existence of the coral-builders ; and on this account their structures are absent from the colder regions of the ocean, and from the mouths and estuaries of large rivers, where the waters are liable to be charged with muddy sediment.

B.—Forms of Coral Reefs.

According to Charles Darwin, coral reefs are capable of being grouped under three great classes, namely :—

(1.) Atolls (or lagoon islands) ;

(2.) Barrier-reefs ; and

(3.) Fringing-reefs.
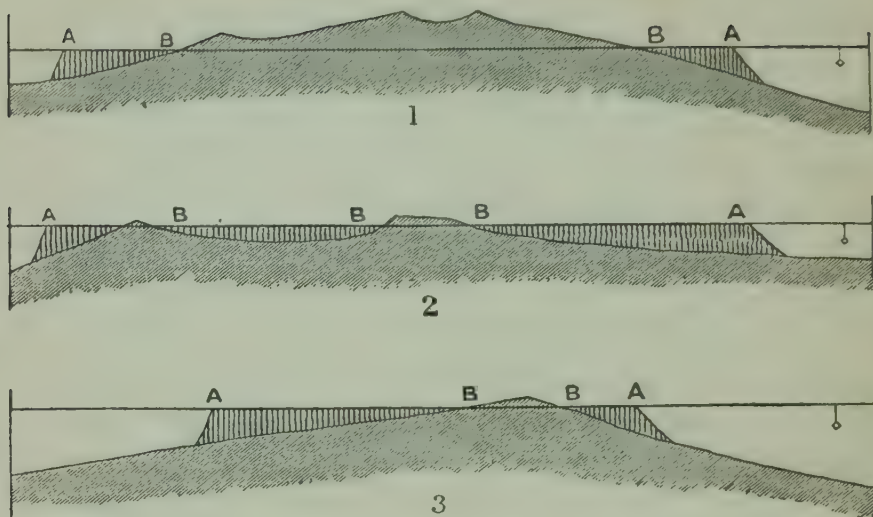
FIG. 6.—SECTIONS TO SHOW STRUCTURE OF CORAL ISLANDS.

No. 1.—Section of Vanikoro Island.
No. 2.—Section of Gambier Island.
No. 3.—Section of Maurua.

The horizontal line is the sea level, from which, on the right, a plummet descends representing 200 fathoms. The light oblique shading shows the section of the land, and the darker vertical shading that of the coral rock. A A, are the outer edges of the reef whereon the sea breaks. B B, the shore of the encircled islands.

(1.) The atolls are found in large numbers in the Central and Western Pacific, and Indian oceans.* They consist of rings of coral rock of various forms and dimensions, generally with one or more gaps through which

---

* G. C. Bourne on the *Atoll of Diego Garcia, &c.,* Proc. Roy. Soc., March, 1888. Atolls are absent from the West Indian region, which are characterised by fringing-reefs.

the waters of the ocean find access to the interior, which consists of a shallow cup composed of either dead coral-rock, shells, or of delicately branching varieties of living coral. These rings of rock rise a few feet above the surface of the ocean, against which the surf is usually breaking even when there is a perfect calm. Cocoa-nut palms and other plants occasionally find a footing on the ridge, forming a ring of stately trees, which at a distance seem to rise directly out of the ocean. The seeds and nuts of the palm have been carried from other lands by the currents, and thrown up on the atoll bank by the waves, in a way which Mr. Darwin has very clearly described in the case of Keeling Island.

Outside the atoll the water descends rapidly to great depths, and the surface of the rock is covered by living polyps of the kinds suited to flourish amidst the breakers and oceanic currents. From the soundings made by Captain Fitzroy on the steep exterior wall of the Keeling Atoll, it was found that, within ten fathoms, the pre-pared tallow at the bottom of the lead invariably came up marked with the impressions of living corals ; as the depth increased the impressions became less numerous, and particles of sand became more and more abundant ; until, at last, it became evident that the bottom consisted of smooth sandy layers. From these and other observations it has been inferred that the reef-building polyps are restricted to a depth of 20 or 30 fathoms, in which the

water is highly aërated, and other favourable conditions, such as that of temperature, are prevalent. Atolls of the Pacific vary in size from half-a-mile to fifty miles across.

A remarkable variety of atoll is one in which the great ring of coral-rock is itself composed of lesser rings. Of this variety the grandest example, perhaps, is that called Tilla-dou-Matte, one of the Maldive group, in the Indian Ocean. This is a large atoll composed of a number of secondary atolls which combine to form its rim, each having its own central lagoon. The Tilla-dou-Matte itself contains a vast lagoon, from which rise a few secondary atolls with lagoons of considerable depth. Mr. Bourne, who describes this remarkable group of coral islets, considers that this compound atoll has originated in a form resembling that of the Great Chagos Bank.*

(2.) Barrier-reefs consist of a wall of coral rock running along the shore of a large island or continent, of which the most remarkable examples are those on the north-east coast of Australia, and on the western coast of New Caledonia. The distance from the coast necessarily varies with the amount of downward slope of the sea-bed.

---

* G. C. Bourne, *supra cit.,* p. 104.

Where the slope is steep, the reef approaches the shore; where it is slight, the reef recedes; and on the outer side the reef plunges down into deep water.

(3.) Fringing-reefs, or as they are sometimes called "shore-reefs," only differ from Barrier-reefs in not having an interior channel of deep water; and of this class the reefs which fringe the island of Mauritius offer good examples.* They extend round its whole circumference, with the exception of two or three places where the coast is almost precipitous; and where, if, as is probable, the floor of the sea is of a similar nature, the coral would have no foundation on which to become attached.

The great barrier-reef of Australia follows the north-eastern coast for a distance of about one thousand miles, its average distance from the coast being between twenty and thirty miles, but, in some places, as much as ninety. The great arm of the sea thus included is from ten to twenty-five fathoms deep, with a sandy bottom; but towards the southern end, where the reef is further from the shore, the depth is greater. The sea outside the reef is profoundly deep.†

---

* C. Darwin, *loc. cit*, p. 69.

† Flinder's *Voyage to Terra Australis*, Vol. ii., also Jukes' *Narrative of the Voyage of H. M. S. Fly*, Vol. i. (1847).

C.—Reef-Building Polyps.

The reef-building polyps are restricted to a depth of 20 or 30 fathoms, and flourish chiefly just below the range of the breakers, in waters highly charged with air. They belong chiefly to the *Astræidæ, Poritidæ, and Madreporidæ*; along with which are the Millepora, formerly placed amongst the tabulate corals, but since referred by Professor Agassiz to the Hydrozoa. Dr. Murray states that the coral reef grows more rapidly on the windward than on the opposite side of the reef or atoll, because the current produced in the surface water by the prevalent winds comes laden with the food on which the polyps subsist, consisting of algæ, foraminifera, radiolaria, infusoria, hydrozoa, medusæ, crustaceans and other forms. On these the reef-building animals thrive, and they afford the carbonate of lime necessary for the construction of their stony skeletons.*

D.—Darwin's Theory of a Subsiding Continent.

After an extensive examination of the coral reefs and atolls of the Pacific, Mr. C. Darwin came to the

---

* From four experiments made by the officers of the *Challenger*, it was found that the calcareous shells and skeletons of these animals, taken from the open ocean, sufficed to provide lime-carbonate to the extent of 16 tons to one square mile of water, 100 fathoms deep.

conclusion that they were built on the higher elevations of a subsiding continent. He inferred that, as the successive heights were submerged, they were seized upon by the coral-builders, who converted them, first into barrier reefs, and ultimately into atolls ; the upward growth of the coral masses having, on the whole, kept pace with the progress of the subsidence of the original land-surface.* This grand generalization was, until lately, almost universally accepted by naturalists, being in harmony with what we know of the interchange of land and sea in past geological ages; for, as South America has been upraised to a large extent out of the ocean in late Tertiary times, as shown by the position of shell beds and coral limestones at considerable elevations, it may be inferred that portions of the bed of the adjoining ocean existed in the condition of land-surfaces, at a time when S. America was very largely submerged.† Darwin's conclusions have, however, been recently called in question by Dr. J. Murray, of the *Challenger* Expedition, who considers that the majority of the atolls are built upon submerged banks composed of the *débris* and skeletons of marine animals; while others are planted upon the summits of volcanic mountains, partially or altogether submerged. In such cases, where the bank, or volcanic summit, comes within the shallow envelope of water required by the reef-building polyps, these plant themselves

---

* *Naturalist's Voyage,* p. 465 *et seq,* and *Coral Islands.*

† In Peru, recent coral limestones occur at a level of 3,000 feet above the ocean, as shown by Alex. Agassiz, *Bull. Mus. Comp. Zool.,* Vol. iii.

thereon, and commence their operations, which are continued till the reef reaches the surface. In some cases it is inferred by Dr. Murray that the summits of the volcanic craters have themselves, in the first instance, been prepared for the reception of coral rock, by the deposition of organic and other sediments.* The evidences of upheaval rather than of depression, amidst the Pacific Islands, are in some places unquestionable, as shown by Dr. H. B. Guppy, in the case of the Solomon Islands.† But such cases need only be considered as local oscillations in a region where volcanic action is prevalent ; and we must recollect that evidence for submergence is seldom accessible to observation. Amidst such a conflict of authoritative opinion, is it not possible to find an explanation which shall be at once compatible with observation, and also fall in, to some extent, with the views of these naturalists, which are so much entitled to our respect ? To the author it does not appear that the views of Darwin and Murray are wholly irreconcilable. Why, after all, may we not suppose that the volcanic mountains and banks of organic materials are themselves planted on a floor formed by the surface of a continent, which once occupied the region of the Central and Western Pacific? For such a conclusion the evidence seems all that is necessary, and is consistent with the theory of reciprocal interchange of level between continental surfaces and adjoining oceanic beds, of which geological phenomena afford numerous examples.

   Proc. Roy. Soc. Edin. (1880) p. 505-9.

† Guppy, *The Solomon Islands : their Geology*, p. 25 (1887).

CHAPTER V.

THE TIDES.

A.—CHARACTER OF THE TIDES.

The daily ebb and flow of the tides is an occurrence familiar to most of the inhabitants of the British Isles from childhood, and the time of high and low water can be calculated, and is actually predicted in our almanacs, because this ebb and flow is governed by known physical laws. If we take up a position on a slightly shelving strand when the tide is setting in, and the surface of the sea is smooth, we can then watch the ripples or little waves as they break on the shore. If, then, we mark on the sand the limit to which one of these waves spreads upwards, we shall find that the second or third wave following it will send its waters still further; and this will constantly recur till the upper limit of the tide has been reached, and the reverse process comes into play. In this case every second or third wave falls a little short of the preceding one, till the limit of low water is

reached. Two returns of high tide, with intervening periods of low tide, recur about every 24 hours ; and as this is the period of the rotation of the earth on its axis, the tide has evidently some connection with this rotation.

B.—Attraction of the Sun and Moon.

That there is a dependence between the tides and the position of the sun and moon was known to ancient philosophers; but Sir Isaac Newton, in his *Principia*,* first laid down the laws of the tidal wave, and his views were still further elaborated by Laplace, who showed, by calculations founded on observations made on the west coast of France, that except where foreign influences, such as storms, chance to interfere, not only the times, but also the inequalities in height of the tidal waters, at any place, may be known by calculation beforehand.† The tides are unquestionably due to the difference of the attraction of the moon, as also of the sun, at places on the surface, and at the centre of the earth. The attraction of those bodies varies inversely as the square of the distance, and therefore the said difference (which is the tidal force) inversely as the cube of the distance. Hence, owing to the very much greater proximity of the moon, her differential attraction is greater, and the tides are

---

* Newton, *Phil. Nat. Princip. Mathem.* Tom. iii., Prop. xxiv. (Edit. 1782).
† Laplace, *Mécanique Céleste*, Vol. ii., (Bowditch Ed., 1832).

more largely the result of her attraction than that of the
sun, although her mass is so much smaller. As the
earth revolves on its axis from west to east, every meri-
dian of longitude is successively presented towards the
moon, and thus that part of the surface is drawn up by
her attractive force. When the part facing the moon
consists of the ocean, the attraction of the waters to-
wards the centre of the earth is lessened, so that the
surface rises above the normal level, and forms a wave
which follows the (apparent) course of the moon in its
diurnal rotation. Owing, however, to the time of revolution
of the moon round the earth, in the same direction as
the earth's rotation, the lunar day is somewhat longer
than the solar, being about 24 hours 50 minutes, conse-
quently the tidal wave varies, from day to day, its time
of arriving at any given meridian ; or, in other words,
each successive tide being later than that of the preceding
day.* Thus, if it is high-water to-day exactly at noon, the
flood will not be full till about 10 minutes to 1 p.m. to-
morrow. After about fourteen days we shall have high
water again at noon ; and, when the moon has fulfilled
her journey round the earth, the third noonday flood will
again recur. The velocity of the tidal wave varies with
the latitude ; so that from the known circumference of the
earth it is easy to calculate that a wave, travelling round
a globe such as ours covered by water, would have a

* Laplace has calculated that the retardation of the tides varies with the declina-
tions of the bodies, being greater in the syzygies of the solstice than in those of
the equinoxes, in the ratio of 8 to 7. *Mécan. Céleste*, p. 792. (Edit. 1832).

velocity of over a thousand miles an hour at the equator, while in the latitude of Greenwich the velocity would be about 600 miles an hour. Owing, however, to the obstructions to the path of the tidal waves of our globe caused by the great continents of Africa and America, which are projected right across this path, and to the variable depth of the ocean itself, irregularities both in the direction and velocity of the wave are produced of such complexity that the rigorous examination of the problem of the tides is altogether beyond the power of mathematicians.*

There is little difficulty in understanding the mode of formation of the tidal wave on the side of the earth facing the moon ; but as there are two tides in about every 24·8 hours it is evident that a second wave must be formed on the side of the globe directly opposite to the first. The cause of this may not seem so apparent at first sight ; but the explanation is as follows :—The attraction of the moon is strongest on the earth's surface next the moon, less at the centre, and less again on the parts beyond the centre ; so that the solid body of the earth, which is attracted as though it was condensed into its own centre, is more powerfully attracted than the ocean water on the off side from the moon, and is drawn away from that water ; and, thus, an effect is produced similar to

---

* On this point, see Article by Prof. C. H. Darwin, on *The Tides, Encyc. Brit.*, 9th Edit. For simplicity we have, as is usually done, taken the tides as *statical*, not as dynamical ; the latter, in a universal ocean less than 14 miles deep, would have *low* tide under the moon (or sun).

that which would result if another moon was attracting
the water from the opposite side. Thus, there is a bulg-
ing of the parts of the ocean which are antipodal to each
other, and between the two are the tracts of low tide,
where the waters are drawn inwards by the same in-
fluences which cause the tidal waves—the inward-draw-
ing force being one-half of the other.

C.—THE SYZYGIES AND QUADRATURES.

Hitherto we have only considered the effect of the
moon's attraction, but (as already observed) the sun also
produces a two-fold change in the tides in consequence of
its (apparent) daily motion round the earth. Its strength,
however, is not so much as one-half that of the
moon, the proportion being nearly as 2 to 5 ; because, as
above intimated, notwithstanding the great mass of the
sun, its vastly greater distance renders the difference of
its attractions on different parts of the earth much less
than in the case of the moon. On the recurrence of the
syzygies, when the attractions of the sun and moon are
in the same line, the highest tides (called " Spring
tides)" are produced. Hence at the times of new
moon (when the moon is between the sun and the earth),
and at full moon (when the earth is between the sun and
the moon), we have a recurrence of spring tides; as under
such conditions the two bodies act in concert, and the

actual tide is the sum of the lunar and solar tides.[*] On the other hand, when the sun and moon are apart by a quarter of a circle (90°) during the quadratures, the moon flood corresponds in time with the ebb due to the sun; and this counter-action has the result of reducing the tides to their lowest magnitude, the actual tide being the difference only of the lunar and solar tides.

D.—Effect of Depth of the Ocean.

Laplace has demonstrated that the depth of the water has an effect upon the height of the tidal wave;[†] and, that the greater the sea, the more sensible will be the tides. In a fluid mass, the impressions which each particle receives are communicated to the whole. Hence the action of the sun, which is insensible in an isolated particle, produces in the ocean such remarkable effects. On this account the ebb and flow of the tides are insensible in lakes and inland seas such as the Caspian. Even in the Mediterranean the tides are very slight or inappreciable.

E.—A Large Expanse of Water necessary for a Tidal Wave.

The formation of a complete tidal wave requires that

---

[*] This subject is very clearly put in Prof. Buff's *Physics of the Earth*, Ed. by Dr. Hofman, (1851.)

[†] *Mécan. Cél.*, Vol ii., p. 650.

the moon (or the moon and sun together) should be in
the zenith of some position on the ocean, while for two
other points they should be on the horizon ; at such latter
points the tide is lowest just when it is highest at the
former ; hence a large expanse of water is necessary.
Even the Atlantic Ocean is not broad enough for the for-
mation of a tidal wave of first magnitude.* The breadth
of this ocean near the equator is only about 45°, or one-
eighth of the circumference of the earth. It is only the
mighty Pacific Ocean, whose immense expanse of surface
embraces nearly half the globe, which has a breadth
sufficient for the production of a perfect tidal wave.
Hence this ocean is the chief source of the tides ; and the
wave formed near the American shore moves grandly
across towards the west till it reaches the Indian Archi-
pelago and the Australian coast, where its course is broken
by the land, and it is obliged to force its way into the
Indian Ocean to the north and south of Australia.

F.—The Atlantic Tidal Wave.

The most important offshoot of the tidal wave is that
which moves northwards into the North Atlantic. Owing
to the configuration of the continental lands on either
side, the course of this wave is constantly deflected

---

* Airy, however, considers that the Atlantic basin is too large for us to neglect
the *direct* tidal action, and that the tides of this ocean derive very little of their
character from the Pacific wave. *Tides and Waves, Encyc. Metrop.*

towards the east from its normal direction, so as ultimately to describe a curve, which, along the coasts of the British Isles and Scandinavia, takes an easterly direction, directly opposite to that with which it started. This wave works its way into the Irish Sea and the North Sea, by two branches moving from the north and south respectively, so as to meet and intersect within the areas of these inland seas themselves. The wave which leaves the equator takes 12 hours to reach the Orkneys, and 12 hours more to reach the Arctic Ocean, off the coast of Novaia Zemlia.

When a free wave runs into shallow water it travels with less velocity and its height is increased; the connection, also, between the velocity and the depth is known. If the Atlantic wave could be considered as a free wave generated in the Pacific Ocean, its velocity of 250 miles an hour would correspond to a depth of 18,000 feet. In the North Sea the wave appears to travel, according to Professor G. H. Darwin, about 45 miles an hour, which corresponds to a depth of 140 feet; this is about the mean depth of that arm of the ocean.

G.—Co-tidal Lines.

A convenient mode of representing the direction and rate of travel of the oceanic wave is accomplished by drawing on the map of the world certain lines, called *Co-tidal lines*, which show the position of high water at the
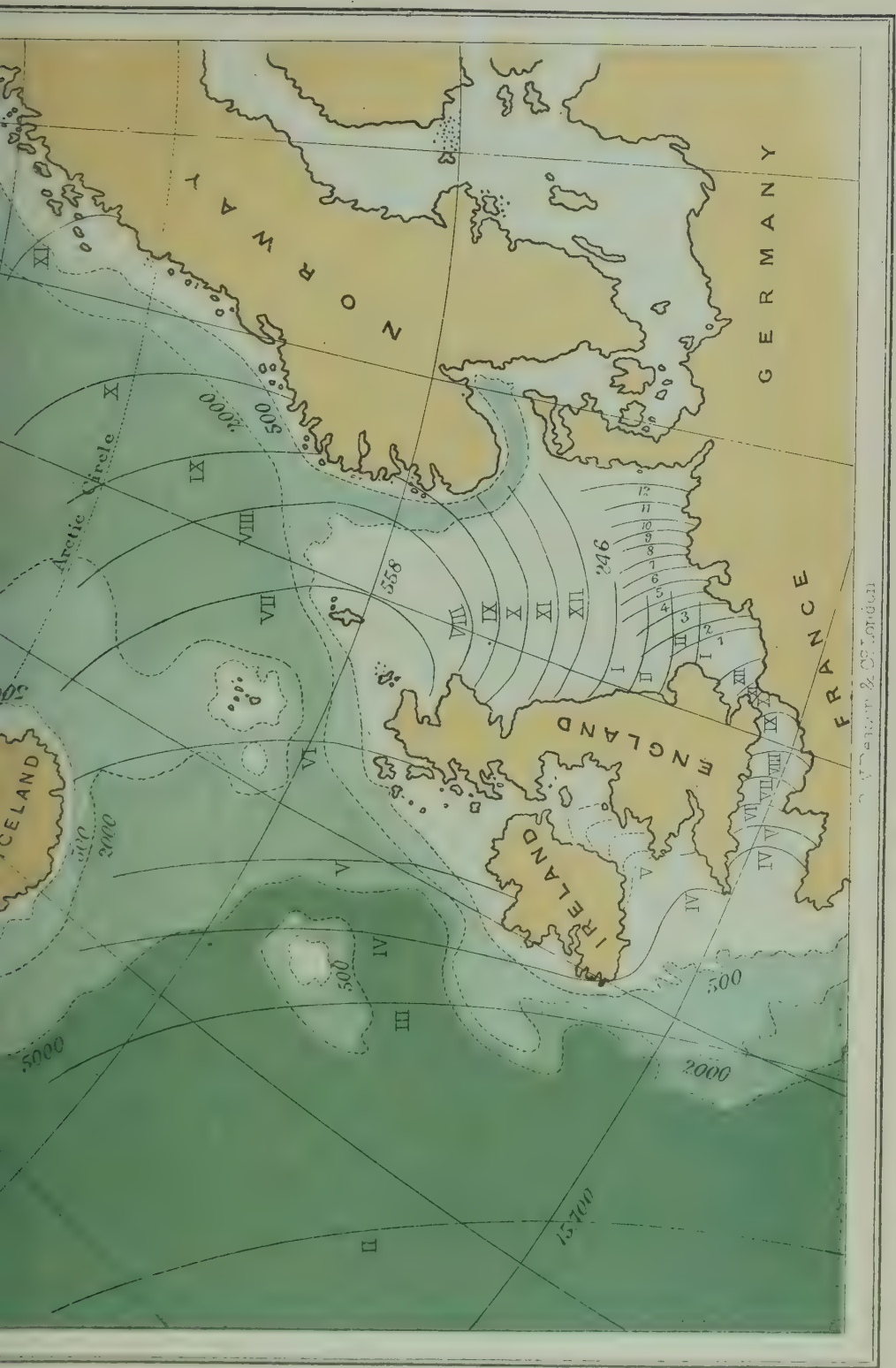
MAP SHOWING COURSE OF TIDAL WAVES AND DEPTHS IN EASTERN PART OF THE NORTH ATLANTIC OCEAN,

Depth given in feet.

same time in adjacent parts of the ocean, and at intervals
of one hour. The line in each case may be considered
as representing the summit of the tidal wave ; and as the
distances between any two lines represent the time of one
hour, they will be found to vary according to the rate of
progress of the wave ; in other words, the distances will
be inversely as the rapidity of motion. As the rate of
motion is greatest over the open and deep oceans, the
distances of the co-tidal lines will here be found greatest ;
on the other hand, when the sea becomes shallow, as
along the eastern coast of Patagonia and the Indian
Archipelago, the co-tidal lines are more or less crowded.

Co-tidal lines were first invented by Lubbock and
Whewell, and founded on a large number of observations
of tides, taken at ports and stations over the globe.*
Their maps have been somewhat modified, but form
the basis of all that have since been produced. It should be
observed, however, that the co-tidal lines in some parts of
the ocean are not as clearly determined as in others. Sir G.
Airy states that, while the co-tidal lines of the North
Atlantic are accurately drawn, those of the South Atlantic
are doubtful, and those of the Pacific east of New Zealand
only conjectural. As the tidal wave has its origin off the
western coast of South America, the course of the wave

---

* *Essay towards a first approximation to a Map of Co-tidal Lines*, by Rev. W.
Whewell, F.R.S., *Phil. Trans.*, Vol. 124, p. 147 (1833). Sir George Airy in the
Art. *Tides and Waves*, *Encyc. Metrop.*, gives another map of co-tidal lines of the
world.

is both west and east, and the consequent numbering of the hour lines is in opposite directions; the latter is, of course, the dominant one, the former the result of reflex action.

H.—Vertical Rise and Fall of the Tides.

In the open ocean the rise and fall of the tide is but slight. Thus at Otaheite the highest tides do not rise more than eleven inches, and at the Sándwich Islands only thirty inches.* At St. Helena they do not rise more than three feet; at Martinique not above eighteen inches; and in the West Indies generally not above four feet. In the Western Pacific, as for instance among the Solomon Islands, the range of ordinary tides varies between 2 feet, and 2 feet 3 inches; except in narrow channels, where the waters are hemmed in, and the rise and fall are greater.† Where, on the other hand, the tidal wave runs into shallow water, and within narrowing coast-lines, the height between low and high water is greatly increased. Thus, in the Bay of Fundy, between Nova Scotia and New Brunswick, the highest tides rise 60 or 70 feet, while at the entrance to the Bay they only rise nine feet. On the coast of Europe, the Bay of St. Malo presents remarkable contrasts during the alternation

---

* Buff, *loc. cit.*, p. 18.
† Dr. H. B. Guppy, *Solomon Islands: their Geology, &c.*, pp. 134-6 (1887).

of the tides. At low water St. Malo itself seems to be sur-
rounded on three sides by wild craggy rocks, covered with
mussels and sea-weed, from amongst which rise up the lofty
walls of the town. A fringe of sea-weed marks upon the
rocks the line which must be reached by the sea, whose roar
is only heard in the distance. And now, a few hours later,
how changed is the scene! The town is almost entirely
sea-girt. The waves are beating round the walls, breaking
at their feet, and throwing the spray sometimes to their
very top. The only communication with the land is now
afforded by a long causeway, the work of man, and the
cliffs which some time since were left high and dry are
now hidden from view. The harbour, left dry at low
water, forms, at flood time, a basin ample enough for
several thousand vessels.

The phenomenon known in the Bristol Channel as
"The Bore" is another result of the entrance of the
tidal wave into a narrowing and shelving strait direct
from the outer ocean. Entering the channel with a high
velocity, the wave is impelled forward, and advanc-
ing up the estuary of the Severn, over the shelving
shore, rises like a ridge above the surface, and breaks on
the banks with dangerous effect. Similar remarkable
results are produced in the Runn of Cutch in India, in
the mouth of the Amazon in America, as well as in the
Bay of Fundy, already referred to. Where two tides
meet, as in the Irish Sea off the coast of Lancashire, the
effect is intensified; on which account the rise and fall of

I

the tides in the Mersey, at Liverpool, amount to no less
than 26 feet (spring) and 20 feet (neap); and special
arrangements, by means of floating stages, are required
for communicating with vessels anchored off the pier.
At Holyhead the rise and fall amount to 16 feet (spring)
and 12 feet (neap); at Dublin, 12 to 14 feet (spring) and
9 to 11 feet (neap).

I.—Tidal Retardation of the Earth's Rotation.

A comparison of recent with ancient eclipses of the
moon goes to show that the earth's axial motion is being
retarded when tested by the revolution of the moon; or
else that the moon is now going faster than formerly;
or both together. The moon's revolution is unquestion-
ably being accelerated, and Laplace considered that this
was sufficient to account for the discrepancy. But Mr. J.
Couch Adams has shown that it is only sufficient to
account for half the discrepancy; and that, therefore,
there must be a real retardation of the earth's motion on
its axis. The contraction of the earth's crust due to
secular cooling, and consequent acceleration, is appar-
ently overpowered by the action of the tides, which are
regarded by astronomers as the agents in causing the
retardation.

In ancient geological times, when the contraction
(expressed by much flexuring and folding of strata) was

more rapid than at present, the acceleration of the earth's rotation due to this may have been equal to the retardation caused by the tides, notwithstanding that the tides were more powerful, owing to the greater proximity of the moon. Both forces (those of acceleration and retardation) have been growing weaker down to the present day, when the balance appears to be on the side of the retarding force.

CHAPTER VI.

OCEANIC CURRENTS.

A.—Their Nature.

The waters of the ocean are in a state of constant and universal circulation, which has a most beneficial effect on the climate of various parts of the globe, as tending to equalize the temperature over the surface of the continents, in distributing moisture, and in preserving uniformity in the constitution of the waters themselves. Speaking generally, the effect of oceanic circulation is to transfer the warm waters of the equatorial to the polar regions; and conversely, to cause the colder waters of the polar regions to move towards the equator.

B.—Directions of Currental Movement.

Were the whole surface of the globe covered by water, a broad belt of the ocean on either side of the equator

filling up the entire width between the tropics, would be constantly moving towardthe west, in consequence of the operation of the Trade winds (*See* page 138), but owing to the obstacles to its course presented by the east coast of South America, by the East Indian Archipelago, and by the coast of Africa, the progress of such a stream is interrupted and the equatorial currents are obliged to break their course, being deflected both towards north and south, giving rise to three double systems of circulation, by which the warm waters of the equatorial regions are carried into the temperate zones.

C.—Cause of Oceanic Currents.

It is now generally conceded that, as Herschel has demonstrated, the proximate cause of the equatorial current is the Trade winds ; and the ultimate cause, the sun's heat acting upon the air of the inter-tropical regions over the surface of a rotating globe. The origin of the Trade winds themselves will be presently explained ; but a comparison of a chart showing the direction and extent of these winds with another showing the direction of the equatorial currents, will suffice to illustrate resemblances between the two phenomena, and to afford presumptive evidence of their direct connection. The secondary currents which branch off in various directions are largely governed by the prevalent winds of special seas ; so that, as Dr. Croll observes, the proper view

regarding oceanic currents is that according to which they are considered as members of one grand system, due to the combined action of all the prevailing winds of the globe, forming one system of circulation.*

D.—The Three Great Primary Currents.

Owing to the causes above explained the equatorial current gives rise to Three Primary Double Currents, which may be thus described.

(1.) *The Atlantic Equatorial.*

This is a double current: the Northern tributary having its origin off the coast of Morocco, from whence it moves westwards towards the West Indies, where it joins its waters with the southern tributary called the South Equatorial Current. This latter moves westward across the Atlantic, along latitude 5° S., in a belt of forty-five miles in breadth, at an average rate of thirty miles per day, and with a temperature of 73° Fahr. Opposite Cape S. Roque it divides ; one branch proceeding southwards along the South American coast to form the Brazil current, the other moving onwards towards the Caribbean Sea and Gulf of Mexico, and ultimately giving origin to the Gulf Stream.

---

* Croll, *Climate and Time*, p. 212.

(2.) *The Pacific Equatorial.*

This is also a double current. The North Equatoria!, originating in the tract lying between latitudes 15° and 30° N., and moving westwards, divides into two arms off the coast of China and the Philippine Islands. The South Equatorial, originating off the coast of Peru, and moving westwards towards the Australian coast, gives origin to a counter current along the line of the equator.*

(3.) *The Equatorial Current of the Indian Ocean.*

This current moves westward along latitude 15° S., and is divided opposite the African coast. The current has no counterpart north of the equator, owing to the position of the Asiatic lands. One branch of this current crosses the equator and enters the Arabian sea ; the other flows southward through the Mozambique Channel, and washes the African coast as far as Algoa Bay. A third branch takes a southerly course off the eastern coast of Madagascar.

From the above considerations it will be seen that the general tendency of all these great oceanic movements is, owing to the position of the continental lands,

---

* The currents of the Western Pacific are very complicated and can best be studied by reference to a physical map.

to produce a double set of rotatory currents, each set lying on opposite sides of the equator.

E.—THE GULF STREAM.

Amongst all the currents of the ocean there is none which has attracted such general interest as that known as " The Gulf Stream," in consequence of its important in-fluence upon the climate of Eastern America, the British Islands and Western Europe. It is not too much to say that, were it not for the calorific effect of this stream on the temperature of these latter countries, their climate would closely resemble that of Canada north of the Gulf of St. Lawrence. The amount of heat carried by this stream into British waters has so marked an influence on the climate, that the mean annual temperature of these islands is higher than that due to latitude by about 12° Fahr. This will be clear upon consulting a map with isothermal lines. (*See* Plate VII.)

The Gulf Stream has its origin in that arm of the South Equatorial Current which branches off opposite Cape S. Roque, and, flowing along the coast of Guiana, enters the Caribbean Sea and the Gulf of Mexico. Throughout this part of its course the stream receives a large accession of heat, the surface temperature opposite Cape S. Roque being 73° Fahr., while on issuing forth from the Gulf of Mexico the temperature has risen to 86°

PLATE IV.

MAP OF THE N. ATLANTIC OCEAN,

Showing the Course of the Equatorial Currents, and of the Gulf Stream.

Fahr., being an accession of thirteen degrees. While flowing through the Straits of Florida the Gulf Stream is 30 or 32 miles broad, 2,200 feet deep, and its rate of motion no less than four miles an hour, or ninety-six miles a day. Off Cape Hatteras the breadth is about 75 miles, and the temperature on a winter's day may be 80° at the surface; at a depth of 500 fathoms the temperature falls to 57°. According to Capt. Maury, the bottom of the Gulf Stream flows upwards along an inclined plane from the narrows of Bemini towards the Mid-Atlantic region.* In the Mid-Atlantic the Gulf Stream has a breadth of over 300 miles, a depth of 1,000 feet, a mean temperature of 65° Fahr., and a velocity of four miles an hour.†

On reaching long. 20° W., the stream divides; one branch entering the Arctic Ocean, where its effects are felt in a considerable elevation of the temperature above that due to latitude; the other returning southwards by the coasts of Spain and Africa, and ultimately taking a westward direction under the action of the N. E. Trade Wind, and joining the South Equatorial Current (as already stated) enters the Caribbean sea, thus completing its circuit.

---

* Maury, *Physical Geography of the Sea*, p. 28.

† Haughton calculates that the Gulf Stream carries into the Temperate and Arctic regions more than one-twelfth of the total heat received yearly by the Torrid Zone from the sun.

F.—The Sargasso Sea.

The centre of the circuit thus formed is occupied by an immense floating island of sea-weed, known as the " Sargasso Sea," formed chiefly by masses of the *Sargassum bacciferum*, which, being in the centre of a whirlpool, seldom escape into the outer current. The position of this floating island is between long. 25° and 65° W. and lat. 18° and 21° N., and it affords a home for myriads of molluscs and crustaceans.* The habitat of the *Sargassum* is in the Gulf of Mexico.

G.—Causes of the Gulf Stream.

The motion of the waters of the Gulf Stream is due to the following causes :—

(1.) The piling up of the waters in the Gulf of Mexico, which forces them to find an outlet through the Straits of Florida.

(2.) Owing to the position of the Bahama banks and the Florida coast line, the waters, on leaving the straits, receive a momentum in a direction nearly due north.

---

* When the ships of Columbus encountered this floating island, on their way towards the New World, the crew supposed they were approaching land.

(3.) Having passed the Promontory of Florida, the direction of the coast changes to North-East as far as Cape Hatteras ; thus, the direction of the current is necessarily changed, and as it proceeds, its course approaches more and more an easterly one. This eastward motion is due in part to the rotation of the earth and the change of latitude, and also to the impulse produced by the anti-trades. The division of the Gulf Stream into two branches in long. 20° W. is caused by the position of the marginal lands of Western Europe, the British Isles, and Northern Africa.

The observations made by the officers of the U. S. Navy, collected and systematized by Lieut. Maury, have shown that, throughout its course over the central Atlantic region, the Gulf Stream flows in a channel of cold water which extends down to the very floor of the ocean.* This cold water has its origin in the polar seas, and is constantly moving southwards along the coast of Greenland ; and, owing to its greater density, it necessarily sinks below the warmer and lighter waters of the Gulf Stream. It is in this way that a counter current is set up, to supply the loss caused by the surface movement of the warmer waters towards the Polar regions in the northern hemisphere ; and observation proves that a similar process is in operation over the region of the southern hemisphere. Some details on this subject will now be given.

---

* Maury, *Physical Geography of the Sea*, Edit. 1856, p. 49.

CHAPTER VII.

OCEANIC TEMPERATURES.

A.—Introduction.

Observations recently made on the temperatures of the deeper parts of the ocean all concur in showing that there is a constant flow of Arctic and Antarctic waters towards the warm zones, constituting, with the flow of warm waters in the opposite directions, a kind of "vertical circulation" of these waters. It has been found, in effect, that when once we descend to a depth beyond 800 or 900 fathoms, the temperature falls to a point not much removed from that at which water freezes. Notwithstanding the cold, however, these depths are inhabited by molluscs, crustaceans and echinoderms, similar to those found in the polar seas.

The inference that a general low temperature of oceanic water prevails at some depth from the surface all over the globe first originated with Sir James Clark Ross, and has been more recently affirmed by Dr. Carpenter and others;

amongst whom may be mentioned Professor Lovén, of Stockholm, from results arrived at from deep-sea dredgings carried out under the Danish Government, by Professor Torrell, in 1861.

B.—Temperature of the North Atlantic and other Waters.

In the North Atlantic a temperature of 40 degrees Fahr. is reached at a depth of about 800 fathoms, and the waters below this gradually decrease in temperature down to that of freezing point. Similar results have been determined in other parts of the world, both north and south of the Equator; from which it becomes evident that the warm waters, such as are found in the Gulf Stream and the great Equatorial currents, are only of shallow depth, and that the great mass of oceanic water is in reality exceedingly cold. Now, as the warm superficial waters of the Equatorial regions are constantly flowing off on either hand towards the Poles, it follows that they must be replaced by the cold waters of the Arctic and Antarctic regions; hence we have an evident cause for the low temperature of the deeper waters of the ocean.

Some special cases of temperature soundings may now be given in illustration of the above statements :—

(1.) *North Atlantic, 300 miles S.W. of Cape Clear.*

(Obtained by officers of H.M.S. " Porcupine," 1869.)

Surface temperature of water   ...   54° Fahr.
Water at 100 fathoms ...   .   51°   ,,
   ,,   1,000   ,, ...   38°   ,,   } constant
   ,,   2,436   ,, ...   36·5ᶜ ,,   } cold

(2.) *North Atlantic, off Cape St. Vincent.*

(Conducted by Dr. Carpenter and Capt. Nares in H.M.S.
" Shearwater," 1871.)

Surface temperature of water   ...   68° Fahr.
Water at 100 fathoms ...   .   57°   ,,
   ,,   1,000   ,, ...   38°   ,,   } constant
   ,,   1,560   ,, ...   37·5° ,,   } cold

**(3.) *South Pacific Ocean, between Fiji Islands and
Torres Straits.***

(Obtained in the " Challenger " Expedition.)

Temperature from 1,300 to 2,650 fathoms found to be
one of constant cold at 35° Fahr.

Similar temperatures prevail in the deeper parts of the
China Sea.

(4.) *Antarctic Ocean.*

(By Sir James Clark Ross in H.M.S. " Venus.")

The temperature at a depth of 1,500 fathoms was found to range from 36° to 39° Fahr. (indicated) ; but corrected for pressure, these would be reduced to 29° to 32° Fahr.

(5.) *Mediterranean.*

(Observations made by Dr. Carpenter.)

In the Mediterranean Sea the temperature of the water below 100 fathoms was determined by Dr. Carpenter to be nearly constant at 54° Fahr. to the bottom. Outside the Straits of Gibraltar, which are only a little over 100 fathoms deep, the temperature of deep water descends to 40·5° Fahr., or 13·5° lower.

(6.) *General Conclusions.*

From these and other examples it may be concluded that the central parts of the ocean consist of an upper stratum of warm water, a lower and thicker stratum of icy-cold water, and an intermediate cushion ranging from 700 to 1,000 fathoms ; and, as it is impossible to suppose that the lower cold stratum derives its temperature from the rocky floor of the ocean itself, the conclusion is inevitable that these waters come from the regions bordering on the Poles.

C.—South Atlantic Ocean.

It may here be observed that the South Atlantic Ocean, beyond 45° S. latitude, is not heated, like the seas which wash the coasts of Europe, by warm currents. On the contrary, it is everywhere open to the entrance of the cold waters of the Antarctic Ocean, which come into contact with Polar ice, and with the numerous floating bergs which fill the waters in some parts during the summer months. In consequence of this, the lands and islands bordering the southern ocean—such as Terra del Fuego, the Falkland Islands, South Georgia, Sandwichland and others—have a considerably lower temperature than the coasts and islands of Europe in similar latitudes. Thus, if we compare the temperature of Port Famine in the Straits of Magellan, and of the Falkland Islands, with that of Dublin—all of which are at nearly similar distances on either side of the Equator—we find the following results* :—

Localities.	Latitude.	Degrees of Mean Temperature.		
		Winter.	Summer.	Year.
Dublin	53° 21′N	39·2 Fahr.	66·3 F.	49·28 F.
Port Famine	53° 38′S	33·08 ,,	50·0 ,,	43·79 F.
Falkland Islands ..	52° 0′S	39·83 ,,	53·24 ,,	46·83 F.
Faroe Islands.. ..	62° 2′N	39·02 ,,	52·88 ,,	44·78 F.

* Buff, *loc. cit.* p. 203.

Thus it appears that the climate of Falkland Islands differs but little from that of the Faroes, although the latter is ten degrees farther removed from the equator; while the climate of Dublin is considerably warmer than that of the Straits of Magellan, both of which are about equally distant from that central line.*

* Observations recorded by Dr. H. Lloyd of temperatures of the sea, taken round the Irish coast, go to show that the water is warmer than that of the air all the year round, but especially in winter time. The mean of all the stations, six in number, show that in summer the excess of temperature amounts to only 0·7 degrees, but in winter to 3·3 degrees.—*Papers on Physical Science*, p. 341, 1877.

CHAPTER VIII.

CURRENTS OF THE AIR.

A.—The Winds: their General Characters.

The envelope of air surrounding our globe, and extending to a distance of 45 or 50 miles from the surface, is constantly in motion; producing not only the variable winds and storms which seem to blow where they list, but permanent winds with a constant direction; so that trading ships are able to shape their courses with reference to them, and hence they are called "Trade winds;" to these we shall first direct our attention.

B.—The Trade Winds: their Position and Origin.

On either side of the equator, and extending throughout a breadth of about 30° North and South, is a region of prevalent winds known as the "North-East" and "South-East Trades." Blowing from opposite directions

MAP OF THE WORLD,

SHOWING AIR CURRENTS

AND

TRADE WINDS.
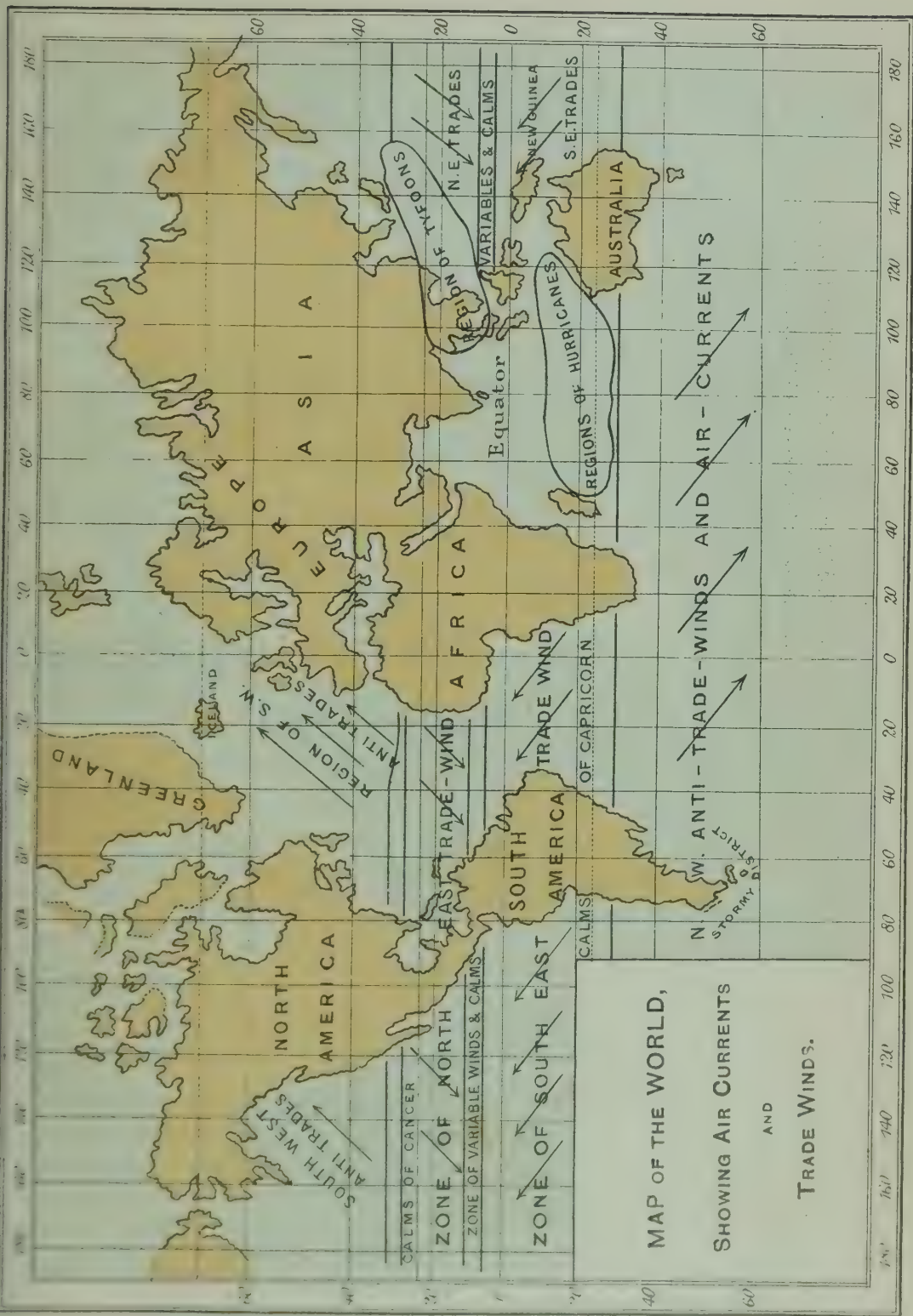
they necessarily meet, and enclose a narrow zone of stagnant air (the zone of calms or variable winds) called " The Doldrums." Along this zone the air ascends, and as it rises becomes cooled and rarified, and ultimately passes away to the north and south, carrying towards the temperate and Arctic regions the warmth of the equatorial. This upper current flows at a great elevation —never touched by the summits of our loftiest mountains —till beyond the limits of the torrid zone. Here, however, it descends to lower levels, and is found, for instance, on the Peak of Teneriffe, even in summer.* In the temperate zone this wind gradually reaches the surface (in summer in somewhat higher latitudes than in winter), and in the North Atlantic regions becomes " the South-west Anti-trade," so prevalent in the neighbourhood of the British Isles.

The existence of the Trade winds, especially of those which blow in the Atlantic, has been recognized since the discovery of America by Columbus. Their long continuance caused much fear amongst the Spanish sailors, who believed that this everlasting east wind would render their return to Europe very difficult. The explanation of their origin is due to the astronomer Halley, who showed, as far back as 1685, that the currents of air on a globe at rest must take directions parallel to the meridians; but that these directions must be very considerably altered

---

* Buff, *loc. cit.*, p. 216.

in the case of a globe, such as ours, rotating on an axis.
In this latter case, the sun's heat, warming the region
of the tropics, causes the rarified and heated air to ascend,
which in turn produces an in-draught of the cooler air,
belonging to the extra-tropical regions, to supply its place.
Now, as the air, thus travelling towards the equator, both
from the north and the south, comes with an initial velo-
city of rotation due to the latitude from which it started,
and as in its course towards the equator it falls short of
that of the earth, the effect is the same as if it were mov-
ing in a direction opposite to that of the earth, namely,
from east to west ; in reality, however, it is moving in
the same direction, but with less velocity. The Trade
winds, therefore, have a compound motion, the resultant
of that towards the west, due to a change in velocity
from change of latitude, and of that towards the equator,
due to the action of the sun's rays, producing an ascend-
ing motion of the air along the Doldrums. The effect
of the friction on the surface of the ocean is to set in
motion its waters in a westerly direction, giving origin to
the great Primary or Equatorial Current described in
Chapter VI.

C.—Region of South-Westerly Prevalent Winds.

Lying to the north of the 30th parallel in the northern
hemisphere is a wide region extending to the Arctic Circle

over which south-westerly winds prevail. These winds
originate in the Doldrums, as already explained ; and
gradually descend from the higher regions of the air,
carrying with them an easterly velocity of rotation due
to the equatorial zone, which, being greater than that
of the earth north of the tropic of Cancer, gives rise to a
westerly current. North of the arctic circle cold polar
currents prevail, being drawn southwards by the ascend-
ing warmer air of the temperate regions. Owing to the
small initial velocity of rotation, these winds necessarily
take an easterly direction, and are prevalent in the spring
months of the year in the British Isles.

D.—Region of North-Westerly Prevalent Winds.

This region stretches southwards in the southern
hemisphere beyond the 30th parallel of south latitude.
The same causes which produce south-westerly currents
in the northern hemisphere necessarily operate to pro-
duce north-westerly currents in the southern temperate
regions. That portion of the heated air which ascends from
the zone of calms and variable winds, and moves south-
wards, ultimately descends towards the surface in the
south temperate regions, and having an eastward velocity
of rotation greater than that of these regions, produces a
westerly current ; or, in combination with the southward
direction, results in the production of a prevalent north-
west current. South of latitude 60° S. the cold polar

winds prevail, which rapidly chill the air of those parts of the globe lying beyond the 50th degree of latitude.*

E.—Cyclones. Districts subject to them. Laws of their motion.

Cyclones, or hurricanes with a rotatory motion, follow the same laws which regulate the directions of ordinary winds. These laws have been investigated and established by Dove, Reid, and Thom,† from observations made in all parts of the world, and partly derived from the log-books of ships in the Indian and other seas. A cyclone arises, in the first instance, from the unequal heating of a portion of the earth's surface, causing the air above it to ascend, and thus drawing in the air of the adjoining regions. Owing to this, such cyclones are frequent along the course of the Gulf Stream in the Atlantic, and their course and rate of progress is so generally understood as to admit of notice being sent by telegraphic communication from America of the time at which they are likely to strike the shores of the British Isles. In such cases, while the centre of the hurricane is moving in a definitely north-easterly direction, the air itself is

---

* These and other phenomena are admirably shown on Keith Johnston's *School Physical Atlas*, plate 17, which the student should consult.

† The late Dr. A. Thom, when in India, and afterwards in the West Indies, collected and tabulated an immense number of observations from ships' log books, by which he arrived at a knowledge of the courses of the dangerous hurricanes of the Indian and Atlantic Oceans, and drew up a report for the Indian Government on the subject, which was adopted and printed at the public expense.

circling round with greater or less velocity, and ascends in a spiral course ; fresh air is at the same time flowing in from the north and from the south to supply the place of the ascending current. This in-draught causes an immediate lessening of the atmospheric pressure, and consequent fall in the barometer, which, if sudden, gives notice of the coming storm.

FIG. 7.—TO ILLUSTRATE THE MOVEMENTS OF CYCLONIC STORMS IN THE NORTHERN AND SOUTHERN HEMISPHERES.
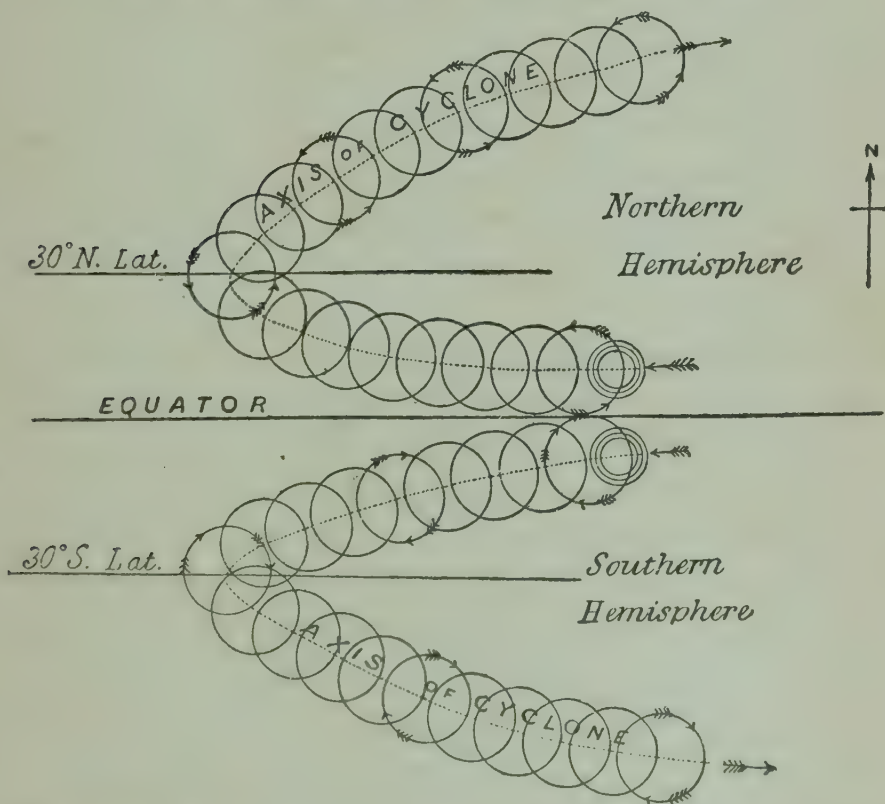
The small arrows show the direction of rotatory motion—The large, the direction of the path of the Cyclones.

It is now well-known, that the direction of rotation of
the cyclonic air is, in the northern hemisphere, opposite
to that of the hands of a watch; while in the southern
hemisphere the direction is parallel thereto. (*See* Fig. 7).
The cause of this is not far to seek, and will be readily
inferred from what has been stated above.

Let us take a simple case by way of illustration.
Suppose that from some spot in the centre of Ireland the
air becomes heated, rarified, and begins to ascend, leaving
a tract of low pressure; then the surrounding air will flow
in to restore the equilibrium. If the current sets in from
the north, and continues for some time, it will be found
that it gradually passes from N. to N.E., and ultimately,
perhaps, to east, owing to the fact that the air comes
from a region where the velocity of rotation is less than
that of the centre of Ireland. Again, if the air flows in
from the south, it comes with a velocity of rotation
greater than that of the place of arrival, and necessarily
results in a west or S. West current. We have, there-
fore, a double set of currents coming in, one from the
north and another from the south, with an ascending
centre, resulting in a spiral movement. By a parity of
reasoning, the direction must be reversed in the southern
hemisphere. When polar currents alternate with those
coming from the equatorial regions the mean direction will
be successively south, east, north, west, and south; and
changes ensue oftener between north and west, or south
and east, than between west and south, or east and north.

Upon these principles we can explain the courses of the cyclonic winds and storms, which to most people appear so inscrutable ; and it will be seen that the explanation is a simple application of the laws according to which the more permanent and invariable air-currents, such as the Trade winds, are originated; both, in fact, can be traced back to two prime causes :—the heat of the sun's rays, and the rotation of the globe on its axis.*

F.—Regions specially liable to Storms. The Monsoons of India.

Some regions of the globe are subject to periodic storms, others to those of an intermittent or uncertain recurrence. Amongst the former may be mentioned the peninsula of India, which, owing to the relations of land and sea under the tropics, is subject to periodic winds and storms, called the *North-east* and *South-west Monsoons.* Over the northern part of the peninsula and adjoining ocean, the north-east wind is prevalent during the winter months, owing to the higher temperature of the air over the ocean, which causes it to ascend and to draw in the colder air of the Himalayan and Thibetian regions. Early in the summer months, however, the process is reversed ; the lands become heated by the sun's rays, and this heat

---

* Trade winds and ocean currents do not cause any retardation in the earth's rotation, being compensated for by the circulatory motion of both.

being imparted to the air, the temperature rises and the air becomes oppresively hot. The direction of the current now changes. In the beginning of April, winds from the Indian Ocean, charged with moisture, move over the land to the north and east, forming great masses of cloud which gather over the Ghauts and along the flanks of the Himalayas. Ultimately, furious storms, accompanied by thunder and lightning, burst over the parched and burning lands, and rain descends in torrents, imparting verdure to the vegetation, and filling the rivers, pools and cisterns with the much needed supplies of water. The annual rainfall on the western coast of the peninsula is very large, amounting at Bombay to 80 inches, and to a much greater depth on the Western Ghauts; at Benares the fall is about 42 inches.

G.—West Indian Hurricanes.

The hurricanes of the West Indies, so well-known for their terrific fury, originate where the belt of the Trade winds passes into that of the storms.* They may be set up either by an encroachment of the South-east Trade Wind, which, after it has passed the equator, gradually strives to take a south-westerly direction in the zone of the "North-east Trades," or by a falling or forcible descent of the upper Trade wind into the region of the lower. The air-

---

* Buff, *loc. cit.*, p. 230.

current thus established, in seeking to press itself into the "North-east Trade," is turned by the resistance of the latter from its own direction toward the north-east, and forced to strike across the West Indian Sea. So long as it remains within the region of the "Trades," the whirl-wind proceeding in this direction takes its onward course almost in a straight line ; but, on leaving the region of the Trades, and entering that of the "South-west Anti-trade," its course bends suddenly round towards the north-east, and it loses much of its force, because the resistance to its passage by the North-east Trade wind is now withdrawn.

H.—WHIRLWINDS OF THE INDIAN OCEAN.

The whirlwinds of the Indian Ocean and the typhoons of the China Seas, lying on different sides of the equator, originate in similar conditions. As an example, we may refer to the track of the Rodriguez hurricane of April, 1843, in the Indian Ocean, which has been carefully mapped. Commencing near the coast of Java, it swept across the Indian ocean towards the Mauritius, with the usual rotatory motion belonging to hurricanes south of the Equator.*

---

* A map of this hurricane is given by Keith Johnson, *loc. cit.*, plate 17

I.—Connection between Barometric Pressure and Direction of the Wind.

No one can have studied the weather charts issued daily from the Meteorological Office in Westminster, without becoming aware that the direction of the wind and the variations in barometric pressure are intimately connected with one another; so much so that, knowing the one, we can predicate with much certainty the other. Not only is the direction of the wind capable of being known by the barometric readings over a line of country, but the force is also determinable; and, except where some local cause of irregularity occurs, the force of the wind will be found to correspond to the barometric gradient; that is to say, the more rapid the rate of increase or decrease of pressure, measured by decimals of an inch, within a limited tract of country, the stronger will be the wind; or *vice versâ.* As regards the direction, a very simple rule, known as " Buys Bellot's Law," will generally be found to hold good :—That if a person stands with his right hand held in the direction of maximum pressure, and his left in the opposite direction, he will then look in the direction towards which the wind is blowing, or it may be put in this form :—" Stand with your back to the wind, and the barometer will be lower on your left hand than on your right." Thus, supposing the position of minimum pressure to be over the Norfolk coast, where the baro-
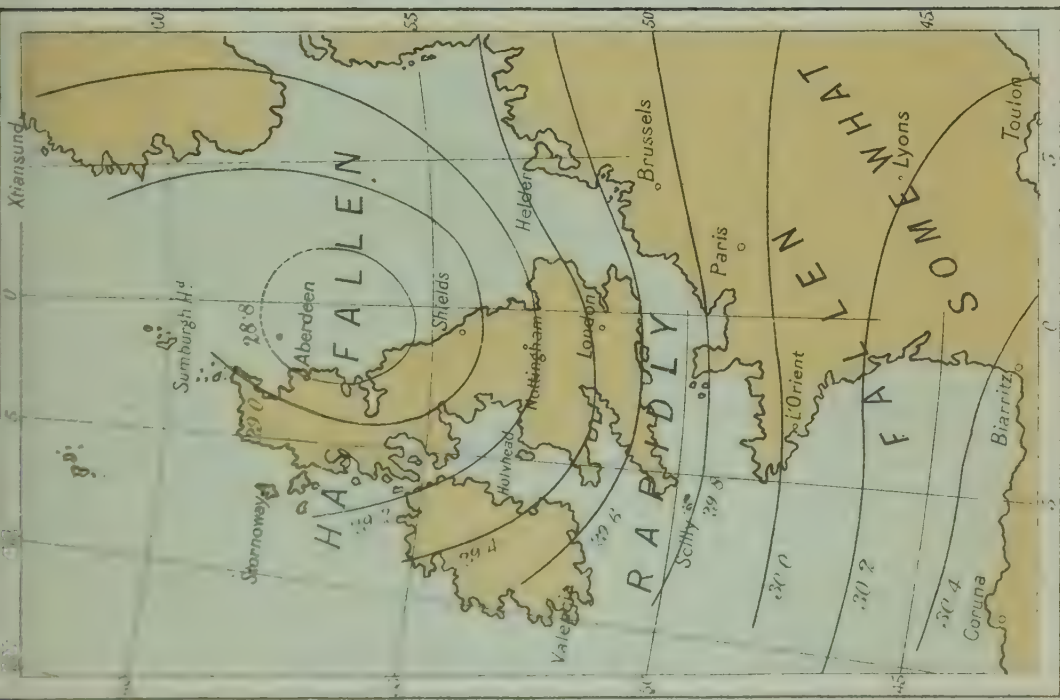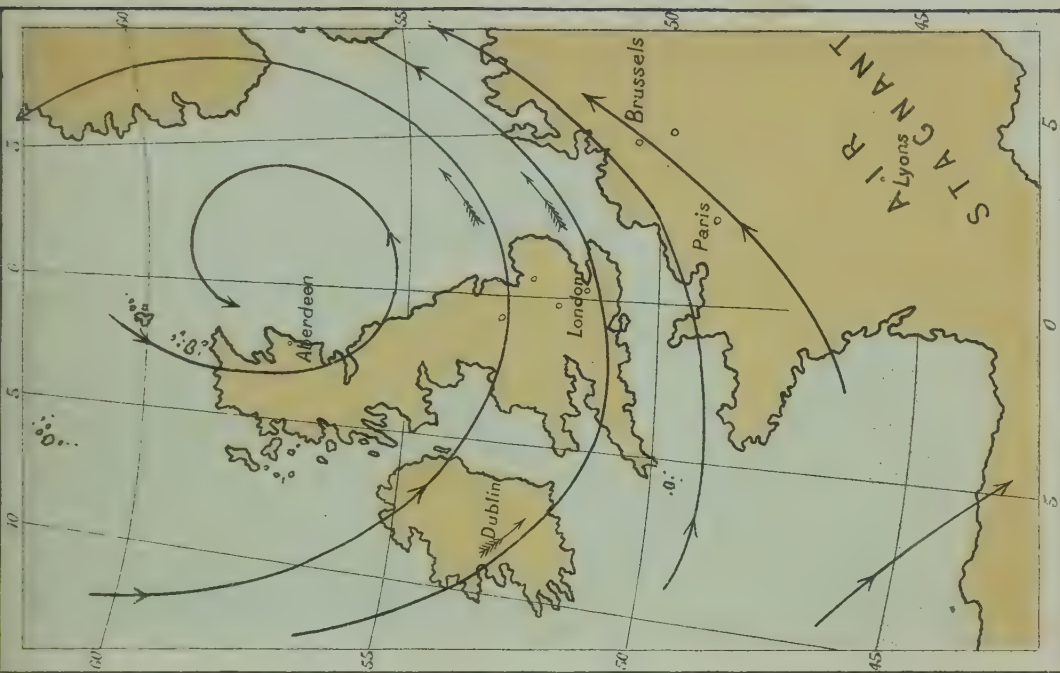
No. 2.— Map showing direction of Wind same time as No. 1.

No. 1.— Map with ²⁄₁₀ inch Isobars

meter registers 29.4 inches, while at Biarritz the reading is 30.2 inches, the direction of the wind will be found to be from west to east along the coast of France.*

J.—BAROMETRIC GRADIENTS.

When the atmospheric pressure varies rapidly in certain directions this variation can be measured by means of the barometer; and in proportion as the variation is rapid or the contrary, the expression a " steep " or " slight " gradient is used to express the amount of variation. In measuring gradients certain constants are used, both for horizontal distance and vertical pressure. Those in use by the Meteorological Office in London are expressed in hundredths of an inch of mercury to one degree of sixty nautical miles. Steep gradients generally indicate strong winds; and in the case of the British Isles, no storm of any serious extent is felt unless there be an absolute difference in the barometrical readings of two of the stations of the Meteorological office exceeding .05 of an inch. One illustration may here be given. The difference in readings between Rochefort and Aberdeen on February 1, 1868, when a tremendous westerly gale was raging, was as much as 1.76 inch; the reading at Rochefort being 30.16, and that at Aberdeen 28.40

---

* Such, for example, were the conditions on Sunday Morning, 26th August, 1877, as shown by the weather charts. The day is not specially selected.

inches. These figures give a gradient of 15.7 on Beaufort's scale over the entire distance of 673 miles.[*]

K.—ISOBARS, OR LINES OF EQUAL BAROMETRIC PRESSURE.

This term is applied to lines traced through stations of any country at which the barometric pressure is the same at the same moment of time. By means of the stations distributed over the British Isles and adjoining parts of Europe, and connected by telegraphic communication, such isobaric lines can be traced on the map. (*See* Plate VI.) These lines are generally curved, and during the progress of a cyclone take a more or less concentric form round the centre of depression. On the other hand, during the prevalence of an anti-cyclone, the isobars are wide apart, the barometric pressure being high and widely distributed, and are arranged round a centre of high pressure. In this case the circulation of the air is in a direction opposite to that in the case of the cyclone; namely, *with* the hands of the watch, in the northern hemisphere.

---

[*] R. H. Scott, *Weather Charts and Storm Warnings* (1876), p. 44.

CHAPTER IX.

TEMPERATURE OF THE AIR.

A.—The Temperature falls as we ascend.

The direct rays of the sun, striking down through the atmosphere, have but very slight influence on its temperature. The lowest stratum of air partakes of the temperature of the ground which becomes heated by the action of the sun, and this warm stratum rising upwards allows colder and heavier air to take its place. This process gives rise to a vertical circulation of the air, most beneficial in its results, as tending to equalize the temperature for a considerable height above the surface of the ground; or at least to diminish the rate of cooling. Nevertheless, the lowering of the temperature as we ascend everywhere takes place at a rate of about $1°.8$ Fahr. for every 500 feet of elevation.

This gradual lowering of the temperature of the air depends much less on the actual loss of heat (since it loses

heat by radiation with extreme slowness) than on its rarification owing to decrease of pressure. As we ascend from the plain up the mountain side the pressure of the air continually decreases, as indicated by the fall of the barometer ; this allows the ascending air to expand more and more, and in so doing it uses up a portion of its heat, which thus becomes combined or *latent*. Ulti-mately, as we ascend into the highest elevations the lowering of temperature becomes so great that, under the equator, snow instead of rain falls on mountains of sufficient height all the year round, and the climate re-sembles that of the Arctic regions.

Although the rays of the sun pass through space, the temperature of the region beyond the limits of our atmos-phere is exceedingly low. Fourier believed that—45° Cent. (or 49° below zero of Fahr.), represented this temperature ; but, since his time, degrees of cold con-siderably lower than this have been observed in the open air.* On the other hand, if we suddenly and forcibly compress air, heat is immediately evolved ; and in deep valleys or low depressions on the surface of the globe the temperature is higher than on adjoining lands of greater elevation owing to the increased density of the air. As a natural illustration the case of the remarkable hollow called " The Ghor," in which lies the Dead Sea,

---

* Even if there were no sun, the stars would contribute something to the tem-perature of space. The absolute zero temperature is calculated to be –273° Cent. See *Ganot's Physics*, 12th Edit., p. 454.

may be cited. The surface of this lake is 1,300 feet
lower than that of the Mediterranean; and in winter
time, when snow often lies on the table lands of Pales-
tine on the one side, and on those of Moab on the other,
the valley of the Ghor is so warm that the Arabs flock
down from the hills around, and pitch their tents over its
surface, in order to take advantage of the comparatively
mild climate which they are always certain to find, even
in the coldest winters.

B.—Effect of Radiation at Night.

When the sky is cloudless, and the air is clear and
still, radiation of heat from the surface of the ground
causes a rapid fall in the temperature of the lower strata
of air. It is owing to this that, in tropical or sub-tropical
climates, the difference between the day and night tem-
peratures is so great. Thus it happens in the valleys
and plains of the Sinaitic Peninsula that, in the winter
months, the temperature rises as high as 90° Fahr. in the
shade, and it falls as low as 36·5° Fahr. before sunrise in
the early morning.*

---

* During a period of twenty days (between the 10th and 30th November, 1883,
spent in the Sinaitic Peninsula, the highest temperature was 90 degrees Fahr. in
the shade, and the lowest 36·5 degrees Fahr. The daily observations were taken
by Mr. Reginald Laurence of the Expedition sent out by the Palestine Exploration
Society.

L

C.—Oscillations of Temperature.

The temperature of the higher strata of the air, so far as it depends on the influence of the heated soil, is subject, of course, to daily and yearly oscillations. The highest daily temperature does not occur till after the maximum on the earth's surface. Thus, for instance, while the greatest heat of the day on the Swiss plains occurs in summer about 3 p.m., Kæmtz found it on the Rigi at an elevation of 5,000 feet, at 5 p.m.; De Saussure found it to occur on the Col du Géant, at a height of 10,000 feet, at 6 p.m.—that is, at an hour when the temperature of the earth was already diminishing. * The more the surface of the ground is cooled at night the colder does the air in contact with it become; but this effect extends to only a small height, because the air that is cooled becomes heavier and ceases to rise. Hence it is that the upper rooms of a house are hotter at the end of a summer's day than those on the ground floor.

D.—Continental as distinguished from Island or Coast Climates.

Owing to the extreme range of summer and winter temperatures observed in the central parts of continents, as compared with the more limited range in the case of

---

* Buff, *loc. cit.*, p. 149.

island and coast stations, the difference in the climate
of these two varieties of land-surfaces has been generally
recognized. This difference is, of course, due to the
proximity of the ocean in the latter case, and of its
distance, in the former. The ocean carries the warmth of
the tropics into the temperate and arctic regions, and
also tends to equalize the temperature of the air over its
surface; and in this way that of the winds, as its own tem-
perature varies but little all the year. The changes in
its temperature are, in fact, confined within the limits of
about 5 to 7° of Fahrenheit, yet fluctuations of 70 to 90°
are not uncommon in inland countries, especially in high
latitudes. At Moscow, for instance, a difference of 141·1°
Fahr. (78·4° Cent.), and at Yakutsk even of 158·4° Fahr.
(88° Cent.) have been observed. *

On the other hand, the variations on island and coast
stations bordering the ocean are comparatively small. It
is well known how, along the western coasts and isles of
Ireland and Scotland, frost in winter is comparatively
rare—or at least never severe. Delicate plants, such as
the myrtle, fig, fuschia, and the *Eucalyptus* (blue gum)
often survive a winter in the open air; while along
the eastern and south-eastern parts of England, and in
the central counties which partake in some degree of the
continental conditions of climate, the winters are often
excessively severe, alternating with high summer tem-

---

* Buff, *loc. cit.*, p. 177.

peratures. The following cases may be cited as illustrations of the comparatively small range of temperature in island and coast stations. *

Places.	Latitudes North	Degrees of Temperature (Fahr.).			
		Means of the			Differences of Winter and Summer.
		Year.	Winter.	Summer.	
North Cape (Norway)	71° 10′	33·52	23·72	43·32	19·60
Eyafiord (Iceland) ..	66° 30′	32·35	20·84	43·86	23·02
Faroe Islands	62° 2′	45·95	39·02	52·88	13·86
Unst (Shetland) ..	60° 45′	46·39	39·33	53·45	14·12
Bergen	60° 42′	47·30	35·96	58·64	22·68
New Archangel ..	57° 3′	44·06	33·26	54·86	21·60
Halifax (Nova Scotia)	44° 39′	43·52	24·08	62·96	38·88
Dublin	53° 21′	49·52	39·50	59·55	20·05
Killybegs (West of Ireland) †	45° 31′	50·80	45·3	56·4	11·10
Lisbon	38° 42′	61·70	52·52	70·88	28·36
Santa Cruz (Teneriffe)	28° 28′	70·61	64·58	76·64	12·06
St. Augustine (Florida)	29° 50′	71·15	59·54	82·76	22·82
Trincomalee (Ceylon)	8° 34′	80·69	78·26	83·12	4·86

* Corrected from Buff's Tables.

† Deduced from Tables by Dr. Lloyd, *On the Meteorology of Ireland, Trans. Roy. Irish Acad.*, Vol. xxii.

Of the above cases, perhaps, the most remarkable example of the influence of the ocean in equalizing the temperature is that of Killybegs, a little town on the North Coast of Donegal Bay, in the West of Ireland, where the winter and summer variation is under 12° Fahr. If we compare this western coast station with a continental station on approximately the same latitude, we shall see how wide is the annual variation. The city of Berlin seems to answer for such a purpose. Here the mean winter temperature is 29°, and that of the summer 66°, giving an annual mean range of 47·5°, and a difference of 37°, as against 50·8° and 11·1°, respectively, in West Donegal. In consequence of the mildness of the climate and purity of the air, some localities on the West of Ireland are well suited as winter residences for persons with delicate lungs, and of these Killybegs, Galway, Clifden, Killarney and Glengariff may be specially mentioned. The winter climate of the South-West of Ireland closely resembles that of Biarritz, on the coast of Spain, at the foot of the Pyrenees.

E.—Limit of the Cultivation of the Vine.

The dissimilarity between continental and insular climates is shown, not only in the difference between the winter and summer temperatures, but also in the contrasts between those of day and night. This has been already referred to, but its effect on plant and animal life remains to be noticed. In the South of England, in

Belgium, and in the Netherlands, where the mean summer temperature is nearly the same as that of the Rheingau and the Palatinate, the day temperature falls short of that in these latter districts, where the hot days alternate with cold nights. In Bretagne and Normandy the nights are less cold, and the days, on the other hand, less warm than in the districts south of Nantes, Paris, Rheims, Luxemburg and Treves, wherein the vine is capable of being profitably cultivated.

In this we have an explanation why the cultivation of the vine, which, though it requires a mean temperature ranging no higher than 48·2° Fahr. (9° Cent.), but must have a long and warm summer, cannot be carried on in France much beyond a line drawn through the cities above-named. It explains, too, why the fig which will not grow in a mean temperature under that of 9° Cent., but does not require so great a temperature as does the vine in order to ripen its fruit, grows extensively and thrivingly in Normandy. In Germany, especially in the Valley of the Rhine above Bonn, the cultivation of the vine is carried on considerably further north than in France, and in Eastern Germany as far north as 52° N. lat., but the grapes only fully ripen in favourable years, and in situations such as the right bank of the Rhine Valley where they receive the maximum effect of the sun's rays. In Asia, the northern limit of grape culture is about 50° of latitude. *

---

* Buff. *loc. cit.*, p. 190.

PLATE VII.

CLIMATOLOGICAL
MAP OF THE WORLD.

SHOWING ISOTHERMAL

LINES OF ANNUAL
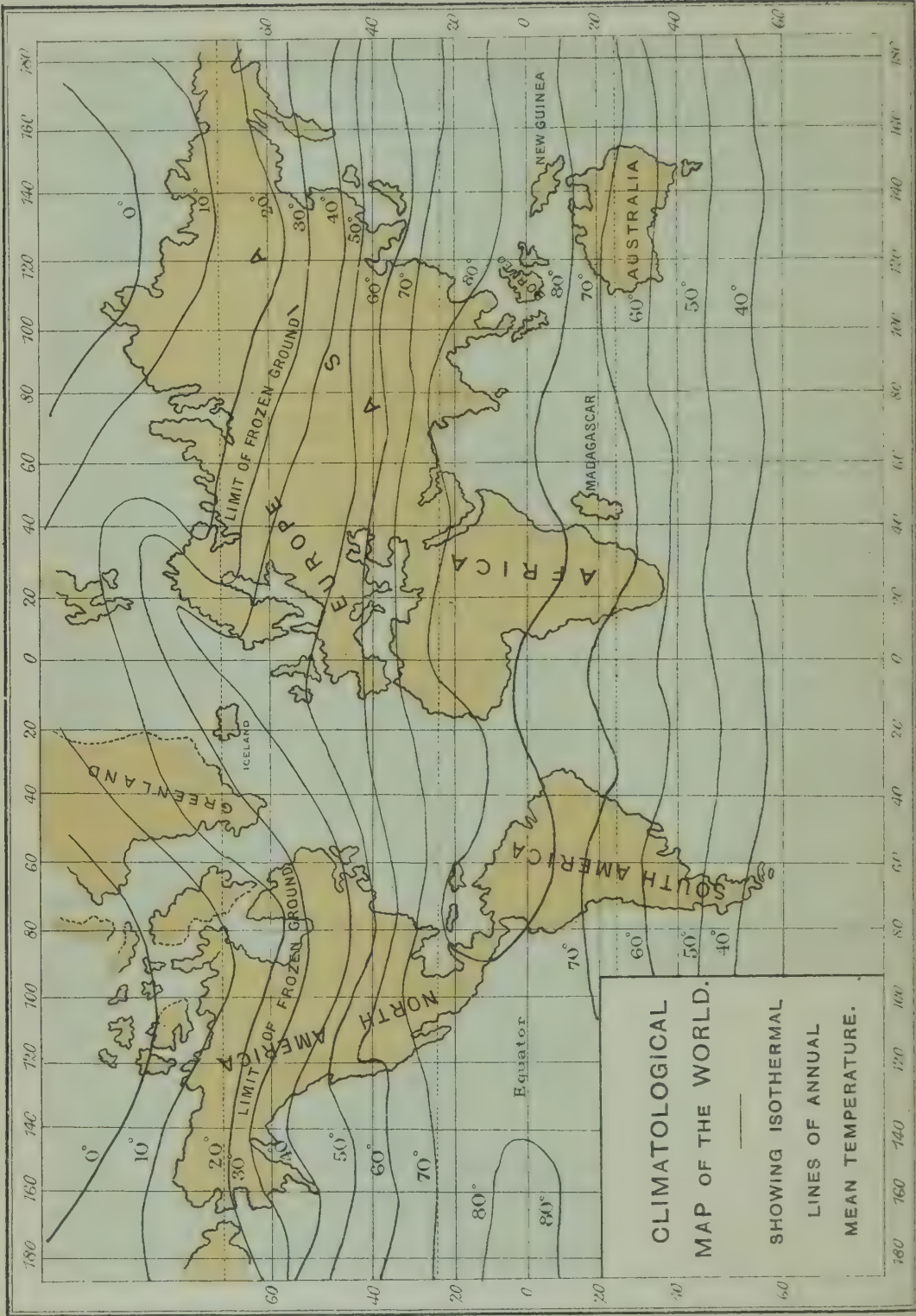
MEAN TEMPERATURE.

F.—Isothermal Lines.

By drawing upon a map a series of lines connecting places having the same annual mean temperature, we have a convenient means of comparing the influence of land and sea upon the temperatures due to latitude (*See* Plate VII.) Similar lines may be drawn for the mean winter and summer temperatures, or for monthly mean temperatures, or any other desired comparisons. Very interesting are the results thus rendered obvious at a glance, especially in the case of the climatological chart of the northern hemisphere. Here we see at once how the influence of the Gulf Stream extends all over the Atlantic and bordering regions north of lat. 45°; owing to which the effects of a high latitude are completely overmastered, and the rigour of an Arctic climate undergoes an extraordinary degree of amelioration. On the other hand, the effects of continental conditions are rendered equally apparent by the descent southwards of the isotherms on reaching the coasts of Europe and America.

G.—The Isotherm of 50° Fahrenheit.

For the purpose of comparison let us follow the course of two of these isotherms, those of 50° and 30° Fahr. That of 50° is of especial interest as it crosses the

central parts of the British Isles, running a little to the north of London and to the south of Dublin, (about lat. 53° N.) On leaving the eastern coast of England, the isotherm bends south, passing by Brussels, Vienna, and touching the 45th parallel on reaching the shores of the Caspian. Having crossed the continent of Asia, it reaches its southern limit on the coast of China, some miles north of Pekin, in the neighbourhood of lat. 40° N.; being 13° farther south than the British Isles.

Tracking this isotherm westward across the Atlantic, we find it reaching the American coast at Boston in lat. 42° N., and thence bending southwards into the centre of the continent to the south of the Great Lakes as far as lat. 40°. In this direction, therefore, the British Isles have an advantage over America as regards annual mean temperature represented by 13° of latitude.

H.—The Isotherm of 30° Fahrenheit.

The bend northwards of the isotherm of 30° Fahrenheit, representing the limit of constantly frozen ground at some depth below the surface, is still more marked on crossing the Atlantic. Owing to the warmth imparted to the air by the Gulf Stream, this isotherm is carried beyond the Arctic circle, entering Europe by the North Cape in lat. 71° N., and America in the centre of Labrador in lat. 55°, that is 16° south of its Atlantic

limit. The influence of these variations in the distri-
bution of plant life we shall consider in a future page.
It is at present sufficient that the reader should clearly
understand that mere difference of latitude is an inade
quate criterion of the character of the climate of any
district; physical conditions of land and sea are much
more powerful factors in determining this character.

I.—Effect of Temperature on Health.

The late Rev. Dr. Lloyd, of Dublin University, has
drawn attention to the apparent relationship between the
annual mean temperatures and the death rate of special
regions, and has arrived at the following conclusions :—

(1.) In the Southern half of Europe the mortality depends
upon the temperature of summer ; being greatest where
the temperature is greatest, and diminishing with it down
to a certain limit.

(2.) In the Northern half of Europe, on the contrary, the
mortality depends on the temperature of winter ; being
greatest when that is lowest.

(3.) The boundary line between these two regions is
not far from the mean yearly isotherm of 50° Fahr.,
which is accordingly the line of least relative mortality.
This line passes through the British Isles.

These conclusions will clearly appear upon an inspection of the following table showing the temperatures above and below those of 50° Fahr., and corresponding death rates of different countries of Europe.[*]

TABLE SHOWING RELATIONS OF DEATH-RATE AND TEMPERATURE.

COUNTRIES.	Excess of Summer Temperature.	Defect of Winter Temperature.	Death Rate per 1,000.
Italy, Turkey ...	+ 25°	...	33
France, Austria ..	+ 18°	.	25
Central Germany..	+ 15°	...	22
British Islands ...	+ 12°	— 13°	21
Belgium	...	— 16°	23
Holland	...	— 18°	26
Prussia	...	— 22°	28
Russia	..	— 36°	38

J.—CLIMATIC CONDITIONS OF THE BRITISH ISLES.

From the above facts it will be seen that the British Isles are as regards health in the position of the most highly-

* Lloyd, *Papers on Physical Science, p.* 405.

PLATE VIII.

MAP
TO SHOW THE LINES OF
ANNUAL MEAN
TEMPERATURE OVER THE
BRITISH ISLES.
(Prof. Hennessy.)

RED LINES, ISOTHERMS.

Wick

Inverness

Aberdeen

Oban

Glasgow

Ed'nbro'

SCOTLAND

Londonderry

Belfast

I. of MAN

Liverpool

Dublin

Manchester

Leeds

York

Hull

Lincoln

IRELAND

47

48

49

50

Cork

51

52

WALES

Stafford

Leicester

Norwich

Northampton

Cambridge

ENGLAND

46

47

48

49
LONDON

Bristol

Oxford

50

51

52

5.3

favoured nation (*See* Plate VIII.)   To their equable climate, or, in other words, the absence of extremes of heat and cold, together with the moisture in their atmosphere, may be largely due, not only the low death rate of their people, but that fairness and beauty of complexion for which the youth of both sexes are remarkable, and which drew forth from Gregory the Great the expression, when observing the British Slaves at Rome, " non Angli sed Angeli, si forent Christiani.* The accompanying map (Plate VIII.) will show how much the annual mean temperature is dependent on proximity to the sea coast ; the interior parts, as Professor Hennessy has shown, being colder than those along the coast for similar latitudes.†

* Bede's *Ecclesiastical History* Lib. II. Cap. I. The whole passage is interesting as showing the effect produced on the mind of the Roman monk by the beauty of aspect and fair complexion of the English youths when exposed for sale in the Roman Forum.

† *On the Distribution of Temperature over Great Britain and Ireland."* Proc Roy, *Irish Academy*, 2 Ser. Vol. iv., *p.* 709 (1888.)

CHAPTER X.

RAIN AND RIVERS.

A.—INTRODUCTORY.

THE fall of rain over the surface of our globe is subject to great variations; for, while some regions are well watered, others have but a scant supply of rain; and there are certain tracts, such as the Desert of Sahara, the plains of Lower Egypt, the table-lands of Arabia, and the desert of Gobi in Central Asia, over which rain never falls, or is so exceptional and uncertain, that they are classed as "rainless districts." To the same category may also be referred portions of Central Australia, of Southern Africa, and of the Pacific borders of Peru and Mexico. Over such tracts vegetation is kept alive by works of irrigation, supplied by the periodical overflow of the rivers which descend from the regions watered by rains. The fertility of the desert-bound valley of the Nile depends on the yearly overflow of that river.

Through thousands of channels its waters are distributed over the plains of Egypt, which, with the aid of a high temperature, are thus converted into tracts of extraordinary fertility, and capable of yielding harvests twice in the year. In ancient times Egypt was called " the granary of Rome," and the capital of the Roman Empire was dependent for its supply of corn on the harvests reaped on the banks of the Nile.

B.—DISTRIBUTION OF THE RAINFALL.

In order properly to understand the origin and distribution of the rainfall of the globe, it is necessary to compare together the chart of the air currents with that of the rainfall. Under the tropics the amount of moisture taken up by the Trade Winds is necessarily enormous. Laden with this moisture, the air ascends vertically along the zone of " Variable Winds and Calms," north of the equator, where the two air-currents (that from the north-east and that from the south-east) meet, and in which rain is almost constantly falling, accompanied by thunderstorms. From this zone (between lat. 5°–10° N.) the upper currents, or Anti-trades, flow off to the north-east and south-east, carrying into the temperate regions vast stores of moisture. As the air ascends it expands, and at an elevation of 16,000 feet it occupies twice the volume with which it left the surface of the sea. It now gradually descends, with a reduced temperature,

and the vapour it contains, being no longer competent to retain the gaseous form, becomes condensed, and, under favourable conditions, descends as rain. At the Peak of Teneriffe, at an elevation of 12,000 feet, the upper current has already descended so as to sweep the summit of the mountain, while a contrary wind is blowing at the base. Further north the upper current sinks lower still, and finally reaches the plains of Europe and the British Isles, where it is the prevalent wind throughout eight or nine months of the year. During this period it discharges its vapoury burden in the form of rain or snow, feeding the springs and rivers, and spreading fertility around.

C.—Physical Peculiarities of the British Isles as regards Rainfall.

Owing to their geological structure the British Islands present a mountainous coast-line towards the Atlantic waters, as shown by the Orographical map (Plate X.), on which account they are favourably situated for receiving large supplies of moisture from the westerly winds on their first reaching the shore. Hence it arises that the rainfall along the western parts of these islands is greatly in excess of that which falls over the eastern and central portions. Thus, if we take a line of country extending from the Thames valley at Kew to the mountains of West Cumberland we find the following averages :*—

---

* Symons, *British Rainfall*, (1886)

PLATE IX.

HYDROGRAPHICAL MAP

OF THE

BRITISH ISLES.

Reference.

Lands on which the
Annual Rainfall is
less than 25 inᵉ

btwn. 25 & 30 „

„ 30 to 40 „

„ 40 to 50 „

„ 50 to 75 „

more than 75 „

NORTH

SEA

Wick

Aberdeen

Perth

F. of Forth

EDINBURGH

Berwick

R. Tees

Solway Firth

York

R. Humber

The Wash

Lincoln

Yarmouth

NORTH

CHANNEL

R. Foyle

Derry

Donegal B.

Belfast

Sligo

I.
of
Man

Chester

IRISH

R. Boyne

SEA

Galway

Galway B.

DUBLIN

Gloucester

R. S

Limerick

LONDON

R. Thames

Cork

Bristol Channel

Plymouth

I. of Wight

ENGLISH CHANNEL

FRANCE
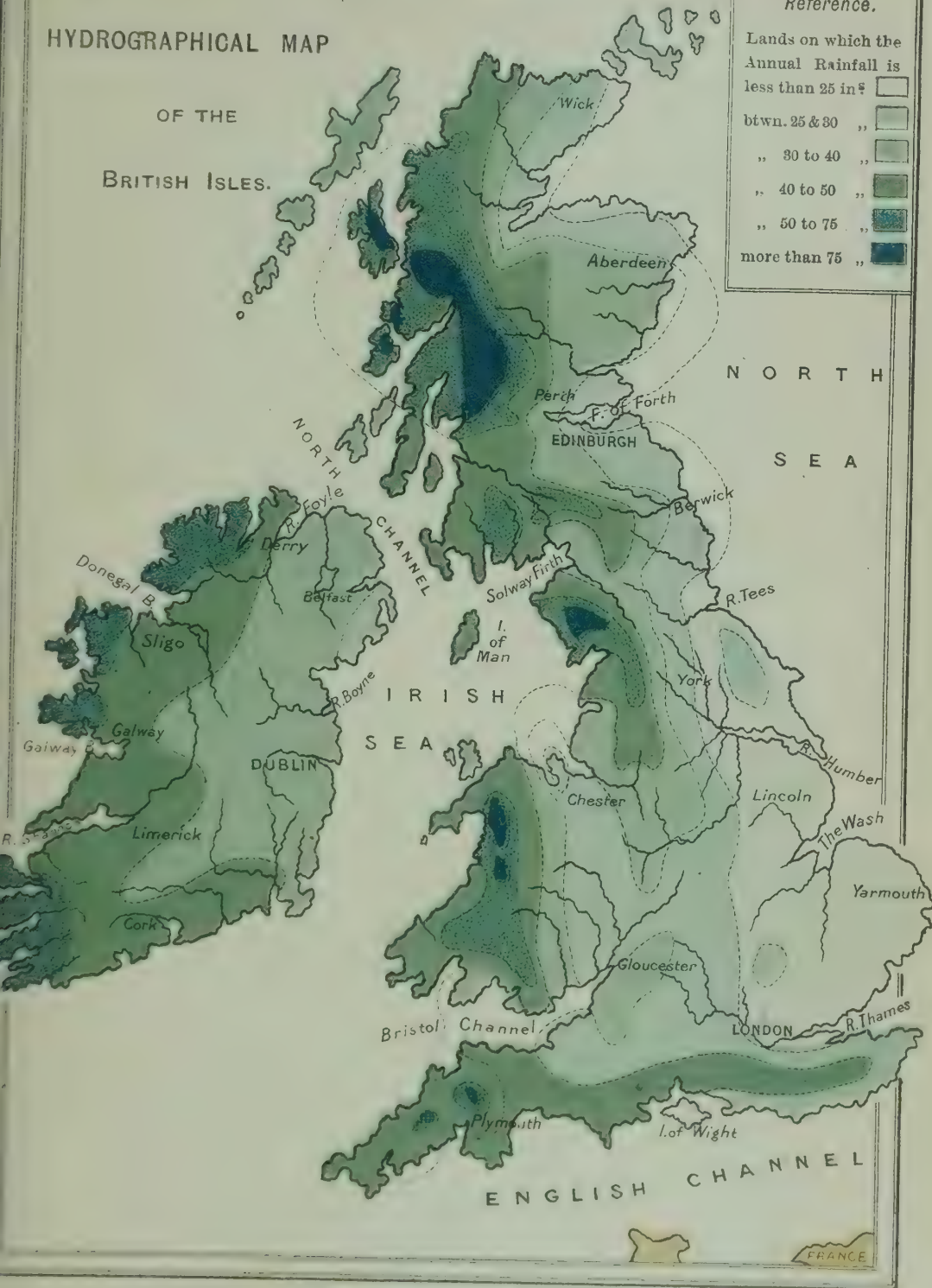
Place.	Average Rainfall, 1860 to 1886.
Kew (Surrey). . . .	24·73 inches.
Northampton . . .	24·25 ,,
Bretley (Derbyshire) . .	31·35 ,,
Bolton (Lancashire) . .	48·10 ,,
Kendal (Westmoreland) . .	55·74 ,,
Seathwaite (Cumberland) .	138·90 ,,

Similar relations between geographical position, altitude of land-surface, and rainfall, are to be observed in the case of Ireland and Scotland, due to the position of the respective portions of the British Isles as regards the prevalent westerly winds. As we proceed northward and eastward over the Europasian region, we find the amount of rainfall to decrease remarkably as compared with the western sea-board. Thus, while the rainfall about Bergen in Norway amounts to an average of 80 inches, at St. Petersburg it has fallen to less than 20 inches, and in Siberia to about 12 inches. In the Arctic regions the precipitation of snow and rain together is smaller still.

The valley of the Amazon in South America presents to us one of the most striking illustrations of the dependence of the rainfall on geographical position and direction of the winds. The valley of the Amazon, the largest river-basin in the world, extends westward to the crest of the Andes, and lies on both sides of the equator. Its head waters, coming from the Andes of Columbia,

Equador and Peru, rise within a very short distance of the
Pacific shore, and traverse almost the entire breadth of
the continent before being discharged into the Atlantic
Ocean. Throughout this vast region the vegetation is
luxuriant, being supplied with an abundance of rain and
moisture brought by the trade winds, which, blowing from
the Atlantic, traverse the continent, and on reaching the
eastern flanks of the Andes discharge their load of
moisture in the form of copious rains and falls of snow.
On the western sides of these mountains we have the
rainless sea-board of Peru, swept by the winds, which,
deprived of their moisture, have passed across the Andes.

D.—RIVERS: THEIR FUNCTIONS IN NATURE.

In a treatise of this kind all that can be done with
regard to the great subject of rivers is to glance at a few
general principles regarding their origin and effects.
Rivers are the natural outlets for carrying off that pro-
portion of the rainfall which is not used up by evaporation;
and as the greatest proportion of the rain falls on moun-
tainous regions, these contain the sources of the largest
rivers, which ultimately drain into the sea. Thus there is
a constant circulation in progress, consisting of evapor-
ation, precipitation, and delivery of the waters again into
the ocean, which was recognised by ancient observers.
Thus we find in the _Book of Ecclesiastes_ the following
remarkable passage:—" All the rivers run into the sea ;

PLATE X.

BRITISH ISLES.

Over 2000 feet

500 ft. to 2000

Under 500 feet
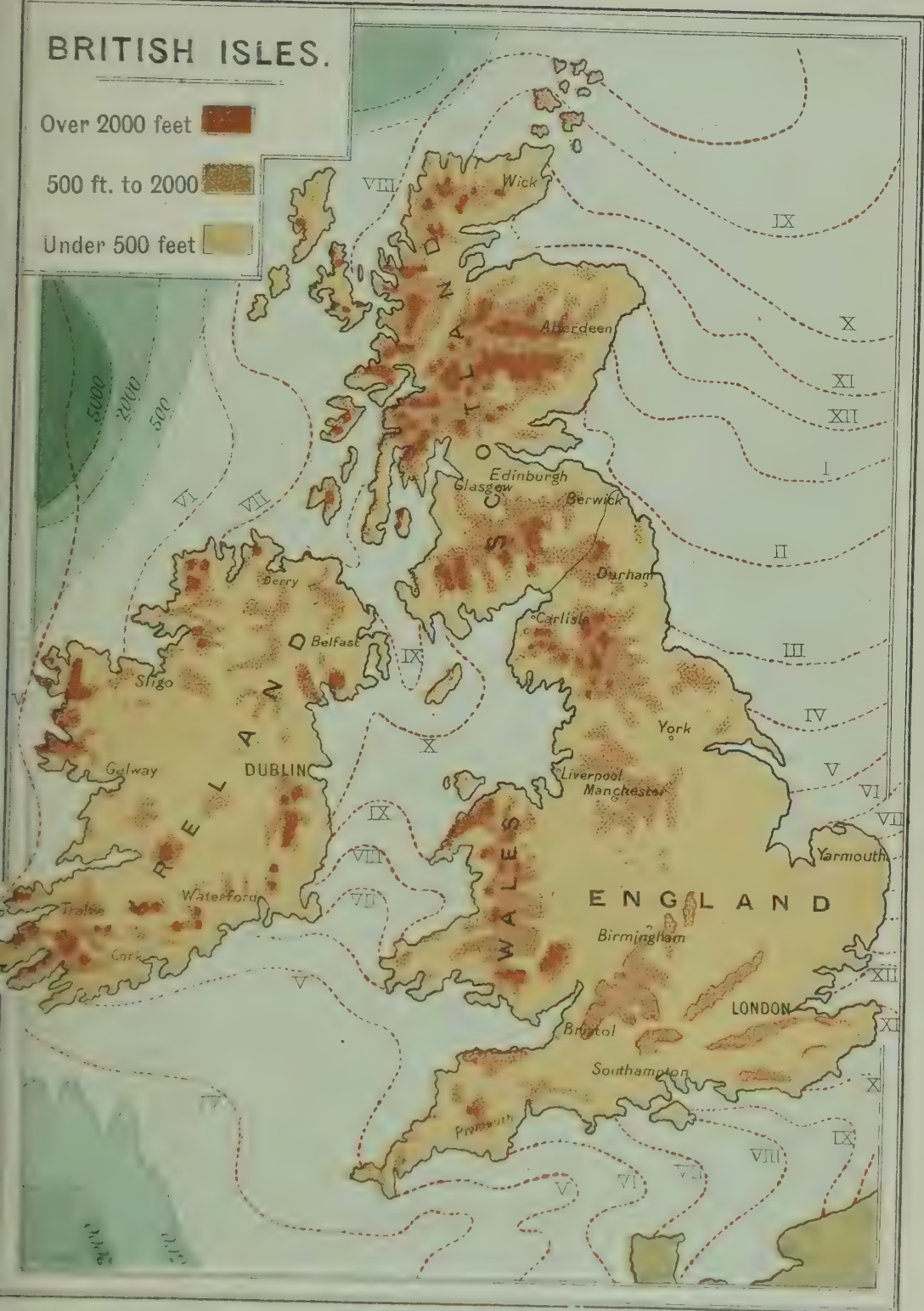
ORAPHICAL MAP OF THE BRITISH ISLES, WITH CO-TIDAL LINES AND OCEAN DEPTHS.

yet the sea is not full; unto the place from whence the rivers come, thither they return again;"* a passage indicating a large acquaintance with the subject of meteoric circulation. The waters of rivers are partly supplied from surface drainage, especially after floods, but partly from springs, which are the sources of supply in the summer months, when the waters are clear, and most largely charged with salts and carbonates in solution. While descending towards the plains, and when the slope is steep, rivers are constantly engaged in cutting down their channels, and carrying away the materials of which the lands are formed towards the ocean; but on reaching the plains and marginal deltas,† the process of erosion gives place to one of deposition ; and the sediment carried down from the interior uplands is deposited at the mouths of the rivers, of which, those of the Nile, the Ganges and Brahmaputra, the Mississippi and the Amazon, afford the most remarkable cases at the present day.‡ The fine sediment annually brought down by the Nile, on which the agricultural prosperity of Lower Egypt so much depends, is derived from the Atbara, one of its tributaries, which descends from the Abyssinian highlands, and is periodically swollen by thunderstorms ; the Blue Nile, which joins the main stream at Khartoum, contributes a share, but not to the same extent.

---

* *Eccles.* I. 7.

† So called from their resemblance to the Greek letter Δ

‡ To these may be added the delta of the Danube where it enters the Black Sea.

M

It may be observed in this connection that rivers which have their sources in large lakes are less liable to fluctuation than those which depend wholly on direct rainfall and springs, as the lakes form natural reservoirs which receive the surplus waters of the rainy season, and discharge them gradually during the remaining parts of the year. The most remarkable examples of rivers with their head waters drawn from lake basins are, in America, the St. Lawrence; in Europe, the Rhone; in Africa, the Nile. In the case of the Po, in Italy, which is liable to extensive floods, some of its tributaries have their origin in the Italian lakes at the foot of the Alps; but the head waters and chief sources of supply come direct from the Alps themselves, and the floods originate in the melting of the snows of winter on the Alpine heights. The cause of the floods of the Nile have already been explained.

E.—THE CHIEF RIVER-BASINS OF THE WORLD.

The catchment basins of rivers are circumscribed either by mountain ranges or elevated plateaux. The summits of these elevated tracts are called "watersheds," and may be almost indefinitely subdivided into smaller branches enclosing the catchment basins of minor streams. We can only here refer to the larger river-basins, with special reference to the continents and oceans.

(1.) *Europe.*

The chief rivers of Europe fall naturally into two systems on either side of the Alps and Carpathians and a low ridge passing across Central Russia to the Ourals :—

(a.) Those flowing northwards into the North Atlantic or one of its inlets ; and

(b.) Those flowing into the Mediterranean Sea, either directly or through the Black Sea and Adriatic.

(a.) To the former belong the Tagus and Douro, the Loire, the Seine, the Rhine, the Oder, the Vistula, the Düna, and the Dwina.

(b.) To the latter, the Ebro, Rhone, Po, Danube, Dnieper, and the Don.

The Volga flows into the Caspian, which has no outlet.

(2.) *Asia.*

The rivers of Asia fall into three great systems :—

(a.) Those flowing northwards into the Arctic Ocean ;

(*b.*) Those flowing eastwards into the Pacific Ocean ; and

(*c.*) Those flowing southwards into the Indian Ocean.

The principal watershed follows the central parts of the continent from the Kirghis Steppes, north of the Sea of Aral, eastwards through the Thibetian plateau to the borders of China near Lake Baikal and the sources of the Amour.

(*a.*) The rivers of the former or Northern system are the Obi, Yenisei, Olenek, Lena, Indigirka and Kolyma ;

(*b.*) Those of the Eastern system, the Yang-tse-Kiang, Hoang-Ho, and Amour ; and

(*c.*) Those of the Southern system, the Euphrates, Tigris, Indus, Ganges, Brahmaputra.

The Lake of Aral, which has no outlet, receives the waters of the Sir Daria and Amoo, as does the Dead Sea those of the Jordan.

(3.) *Africa.*

The rivers of Africa follow the lines of three great systems : —

    (*a.*) Those flowing northward into the Mediterranean ;

    (*b.*) Those flowing eastward into the Indian Ocean ;

    (*c.*) Those flowing westward into the Atlantic.

The watershed between these systems appears to be composed partly of mountain ranges and partly of elevated table-lands.

(*a.*) Of the first system the Nile is the sole representative. Rising in the great lakes under the equator it flows northward, and receiving the tributaries from the Abyssinian highlands, finally enters the sea through the plains of Lower Egypt by means of two principal outlets

(*b.*) Of the second system are the Rovuma, Zambesi Save, Bembe, Maputu, St. John's, and Great Fish rivers.

(*c.*) Of the third system are the Senegal, Niger, Ogowai, Congo or Livingstone, Cunene, Orange, and Oliphant rivers.

(4.) *America.*

North America.—The rivers of this continent belong to three easily distinguishable systems :—

    (*a.*) Those flowing into the Arctic Ocean ;

    (*b.*) Those flowing into the North Atlantic, including Hudson's Bay ; and

    (*c.*) Those flowing into the North Pacific Ocean.

The watershed follows in the main the line of the Rocky Mountains, but sends an important offshoot eastward across the Continent to the south of the Great Lakes, dividing the waters of the Mississippi basin from those of the St. Lawrence. The water-parting of these hills is only 1,500 feet above the sea.

(*a.*) To the first (or Arctic) system belong the Colville, Mackenzie, and Great Fish rivers.

(*b.*) To the second belong the Severn, Albany, Moose, Maine and other streams draining into Hudson's Bay ; the St. Lawrence, St. John, Hudson, Susquehanna, Alabama, Mississippi, and Rio Grande.

(*c.*) To the third (North Pacific) belong the Yukan, Simpson, Fraser, Columbia, and Colorado rivers.

South America.—The rivers of the South American continent belong to two systems only :—

> (*a.*) Those draining into the South Atlantic, on the one hand ; and
>
> (*b.*) Into the South Pacific on the other.

(*a.*) Of the former there are the Magdalena, Orinoco, the Amazon, San Francisco, Rio de la Plata, Colorado, and Negro.

(*b.*) Of the latter there are only a few insignificant streams descending from the slopes of the Andes directly into the ocean.

The South American continent is peculiarly circumstanced from the fact that the giant chain of the Andes, which gives rise to nearly all the great rivers, rises almost directly from the shores of the Pacific ; in consequence of which the great river systems traverse almost the entire continent from west to east, and flow into the Atlantic. It is this which lends to the Amazon its ascendancy above all the rivers of the globe. Its river-basin encloses an area of 2,200,000 square miles ; that of the Obi coming next, but far behind in area, and even that of the Mississippi falling short by nearly 1,000,000 square miles. In every respect the Amazon, which has been called the " Mediterranean of South America," is the greatest river on the globe, affording a water-way from the Atlantic to the very base of the Andes.

The following are the areas of the great river-basins *:—

Amazon . . . . . . 2,200,000 square miles.
Obi . . . . 1,295,000 ,, ,,
Parana and Paraguay 1,250,000 ,, ,,
Mississippi . . . . 1,235,000 ,, ,,
Nile (uncertain) . . 1,100,000 ,, ,,
St. Lawrence . . . 1,099,000 ,, ,,
Yenisei . . . . . 896,000 ,, ,,
Amour . . . . . 870,000 ,, ,,
Yangtse . . . . . 845,000 ,, ,,

F.—Cañons of North America.

Amongst the most remarkable of river-channels in the world are those which penetrate the table-lands of Colorado, and are known by the name of "Cañons." Nowhere can the results of river erosion be more vividly brought home to the mind than when the spectator takes his stand on the upper surface of the Colorado plateau, and traces the line of one of these profound river channels, cut down for thousands of feet into the horizontal strata which rise in stupendous mural cliffs on either hand. The Grand Cañon of the Colorado River is 300 miles in length, and in some places more than 6,000 feet in depth.

---

* Johnston's *School Physical Atlas.*

On either side the palæozoic strata rise in vertical walls, separated by terraces, up to the level of the plateau-surface, and, at the mouth of the cañon, break away on either hand in a grand mural escarpment. For the formation of this and other cañons it is required that the river by whose action the channel has been eroded should have its source in a region beyond the cañon, and that the region through which the channel is cut should be almost rainless. Such is the case with the Colorado River, which has its source high up amongst the Rocky Mountains. Were rain and river action general over the surface of the plateau, the banks would be worn down into slopes, and the gorge-like character of the channels would be destroyed. It is probable, however, that the cañons of the Colorado region were originally excavated at a period when the present streams were larger and more effective than at present. Some of the eroded valleys are now dry; and in others the present streams are but miniature representatives of those which formerly flowed in their channels.*

G.—TRANSPORTING POWER OF RIVERS.

The transporting power of rivers depends on three conditions :—

* Dr. J. S. Newbury, *Geological Report, Colorado Explor. Expedition,* under Lieut. Ives," p. 42. (1861). J. W. Powell, *Exploration of the Colorado River, &c.,* (1875.) Capt. C. E. Dutton, *Tertiary History of the Grand Cañon District, with Atlas,* (1882.)

(1.) The volume and velocity and the current.

(2.) The size, shape, and specific gravity of the matter to be moved ; and

(3.) The chemical composition of the water ; saline waters being more buoyant than very pure or fresh, and causing rapid precipitation of muddy sediment.

According to the calculations of Hopkins, the moving force of a current, estimated by the weight of a block of any assigned form and material, increases as *the sixth power* of the velocity of the current.* It is on this account that, reasoning from the power of ordinary currents of two or three miles an hour, we are liable to miscalculate so entirely the force of a rapid torrent. If a stream, which, with its ordinary velocity (say) of about two miles per hour, can just move along pebbles weighing an ounce, has its velocity doubled in consequence of a flood, it will then be able to carry along stones weighing about four pounds. It is only necessary to examine the bed of any of the rivers descending from the highlands of the British Isles, or of other countries, to become convinced of the enormous power exerted by streams when in flood, and descending steeply towards the sea.

* *Quart. Journ. Geol. Soc.*, Vol. viii., p. xxvii., (1852.)

We are astonished at the size of the blocks, many tons in weight, which have been carried along; but we forget, perhaps, that these huge blocks, standing high and dry in the summer time, are almost entirely submerged in the torrential floods of winter, and are not only urged along by the impetuous current, but lose two-thirds of their weight in consequence of the submersion.*

H.—Evidences of former more extensive River Action. A Pluvial Period.

What has just been stated in reference to Western America applies equally to portions of the Eastern hemisphere. Throughout some regions of Europe, Asia and Africa we are constantly supplied with evidence that the present rivers are in many cases but diminutive representatives of their former selves, and that in others, rivers which once existed have altogether disappeared; so that, at a period not far distant, river-erosion was vastly more effective than at the present day. Space does not permit that we should go at any length into the proofs of this proposition; but we may point to the remarkable waterless gorges, sometimes over a thousand feet in depth, which descend from the table land of Southern Palestine to the shores of the Dead Sea, or to the Valley of Jordan. The Dead Sea itself formerly stood at a level about 1,300 feet higher

---

* Those who wish to pursue this subject, may consult with advantage, Dr. Geikie's *Text Book of Geology*, p. 345, Edit. 1885.

than at present, and occupied the whole valley from the Lake of Merom on the north, to a point in the Arabah valley, about 30 miles south of the present basin, thus forming a lake 150 miles in length.*   This lake has fallen to its present proportions mainly through the diminution in the rains and rivers of a past period, to which the name of *Pluvial* may well be applied.   The old river-beds of Central Africa tell the same tale.   Dr. Livingstone has left us valuable information on this subject.   Speaking of the South-Central parts of this Continent where water is so scarce that the traveller might perish for lack of the necessary fluid, he says, " The country is intersected by valleys in all directions, once the beds of great rivers whose course was mainly south."   To Northern Africa, as Theobald Fischer has shown, a similar observation applies,† and no one can have travelled along the magnificent valleys of the Sinaitic Peninsula, and those of the region bordering the Red Sea on either side, without coming to the conclusion that these generally waterless valleys were once the channels of large and powerful streams.‡

* *Physical Geology and Geography of Arabia Petræa, Palestine, &c.   Memoirs Palestine Exploration Society*, pp. 79 and 113, (1886.)

† *Studien über das Klima,* (1879.)

‡ There is cause for believing that the rainfall of India has, also, recently decreased.   *See* Medlicott and Blanford, *Geology of India,* Part i., p. 417, (1879).

CHAPTER XI.

SNOW AND GLACIERS.

A.—INTRODUCTORY.

In a former chapter I have endeavoured to explain the cause of decrease of temperature as we ascend into the higher regions of the atmosphere; one of the consequences of this decrease is that, on mountains sufficiently lofty, the moisture of the atmosphere is precipitated in the form of snow. This takes place at lower levels as we proceed northwards or southwards towards the poles; so that differences in altitude on the surface of the globe correspond to differences in latitude. Thus it happens, that under the equator itself, we may ascend from the burning plains at the base of a mountain, through zones representing the sub-tropical and temperate climes, till near the summit we reach a climate corresponding to that which maintains all the year round at the North Cape or in Iceland, and find ourselves in a region where perennial snow covers the ground. Such is the case with reference to Mts. Kenia and Kilimandjaro in Africa,

which reach an altitude of about 18,000 feet, and of the Andes of Quito in South America, which attain an altitude of 22,000 feet immediately under the equator.

B.—THE SNOW-LINE : ITS NATURE AND CAUSE.

The presence of perennial snow, either on mountains or plains, is due to the predominance of all the causes tending to its accumulation over those tending to its waste or melting; hence, it does not follow that the snow never melts, or that rain never falls upon the regions of perpetual snow, but only that the accumulation should be in excess of the waste. According to Prof. J. D. Forbes, the annual mean temperature of the Snow-line varies according to latitude ; thus, under the equator it is about 35° Fahr., amongst the Alps and Pyrenees, about 25°, and in Norway (Lat. 68° N.) about 21°. It would seem, therefore, that the presence of perennial snow depends partly on the annual mean temperature, and partly on the amount of snow-fall. As we de-scend from the regions of perpetual snow towards the valleys of some mountain mass, such as the Alps or Pyrenees, we reach a zone wherein the mean temperature is higher than that required for the presence of constant snow, and from which snow is absent in the summer months; hence it is easy to understand that in every such region there is a limit of height for the perennial snow, not liable to much variation throughout considerable

tracts, and, as seen from a distance, marking a definite line along the mountain sides, above and below which the conditions are remarkably contrasted ; snow above, dark, almost naked rock below. Such a line is called *the Limit of Perpetual Snow*, or more briefly the *Snow-Line*.

C.—LEVELS OF THE SNOW-LINE IN VARIOUS COUNTRIES.

The traveller who has had the opportunity of beholding the range of the Swiss Alps from the crest of the Jura Hills, and has looked across the great valley of the Rhone, is not likely to forget the magnificence of that view, or the striking aspect of the snowy region, as contrasted with that which lies below it, throughout a distance from left to right of about thirty miles. As seen from this position, the Snow-line is level and clearly defined. Above, and reaching to the summit of Mont Blanc itself, is a region of dazzling and ethereal brilliancy, glistening in the sunshine, or here and there enfolded in fleecy wreaths of cloud. Below, masses of rock, almost black by contrast with the snow-land above, descend into the region of the pines, which in turn gives place to the verdant valleys and plains, broken by occasional crags and isolated hills, leading down to the margin of the lake which fills the lap of this the grandest of Swiss valleys.*

---

* This enchanting view used to be seen by travellers from Paris to Geneva, when the journey was made by coach across the Jura from Dijon. Now, however, since the opening of the railway, it is seen by few, and much to the loss of the many.

The level of the Snow-line has been carefully determined for all regions where perennial snows are found; the principal of which are, for the Eastern Hemisphere, Iceland, Norway, the Alps, the Pyrenees, the Caucasus, the Himalayas; and for the Western, the Andes of Patagonia, Chili, Peru, and Quito in South America, the Cordilleras of Mexico, and portions of the Rocky Mountains in the Northern Continent. The great peninsula of Greenland is almost entirely covered by snow, which sends down glaciers into the Greenland Sea.

The Snow-line nearly reaches the sea-level at the north of Spitzbergen, in latitude 80° N. In the Antarctic regions, according to the observations of Sir James Ross, the Snow-line descends to the sea-level between latitude 67° to 70°, so that the Southern Hemisphere is much colder than the Northern in circumpolar regions. A great sheet of ice and snow seems to surround the South Pole.

The following are the levels of the Snow-line of the above :—

MOUNTAINS.		Height of Snow-line in feet.	LATITUDE.
Norway	Alten in Fin-marken ...	3,480	70° N.
	Dovre Field	5,200—5,360	62° 2′ N.
	Hardanger ,,	3,800 W. Side, 4,150 E. ,, 4,500 S. ,,	59° 60′ N.
Alps	Swiss Side..	8,100—8,200	46° 5′ N.
	Italian ...	9,000—9,500	
Pyrenees	N. Side ...	9,260	42° 30′ N.
	S. ,, ...	8,300	
Caucasus		10,400	42°-43°N.
Himalayas*	N. Side	18,600	30°-31°N
	S. ,,	15,500	
Cordilleras of Mexico...		14,100	19° N.
Andes of Quito		14,800	0°-2° S.
,, Chile		13,800	33° S.
Tierra del Fuego... ...		3,480	54° S.

* In the case of the Himalayas, the difference of level of the snow-line on the north and south sides is owing to the greater precipitation of snow on the latter, which more than counterbalances the differences of temperature.

D.—Glaciers : their Origin and Office in Nature and Laws of Motion.

Glaciers are to snowfields what rivers are to lakes and drainage basins. They are the channels by which the vast accumulations of snow in certain districts find an outlet, and they are present in nearly all regions where there are large masses of perennial snow. The term " stream of ice " is peculiarly applicable to them, as it has been found that the motion of a glacier down a valley, though very slow as compared with that of most rivers, is not unlike that of a river along its channel.

Glaciers, then, may be regarded as rivers of ice, having their sources in the snowfields which occupy the higher eminences of many mountain ranges; and, flowing down the valleys far beyond the limits of perpetual snow, ultimately dissolve away on reaching a lower level. They consist essentially of ice, generally of a deep azure hue, and perfectly clear, and possessing a banded or veined structure, due to the alternation of bands of cellular, whitish ice, with others formed of compact, blue, glassy ice, which on weathering stand out beyond the more cellular bands.* The change from snow to ice takes

---

*For an account of the historical part of the subject, the reader may consult Tyndall's *Glaciers of the Alps* (1860.)

PLATE XI.

EYE SKETCH

OF THE GLACIER

OF

ALLALEIN

IN THE VALLEY OF SAAS.

(*Prof. J. D. Forbes.*)

SECTION IN C.D.

TERMINAL
MORAINE

D

Gl. RIVER

TO SAAS.

NEVÉ

Gl. OF ALLALEIN

C

B

MORAINE

SECTION IN A.B.

MATMARK
SEE

TO DISTIL BERG
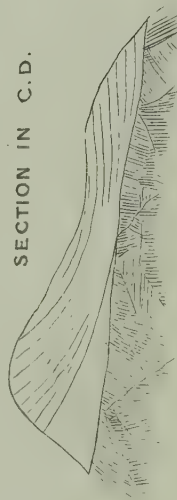
place to a great extent at that part of the glacier where it merges into the snowfield, known as *the Névée ;* and the glacier, in places where the descent is steep, is rent by vertical fissures, known as " crevasses," which radiate upwards from the sides towards the centre, and are caused by the strain due to the faster motion of the centre than of the sides. The surface is partially occupied by masses of rock and *débris*, which accumulate along the sides, and also form long trains down the central parts. These masses, called " moraines," are derived from the cliffs which overlook the glacier, fragments from which from time to time fall on its surface. These, sometimes immense, trains of fragmental matter are deposited at the end of the glacier, forming "terminal moraines," and at this point a muddy stream of ice-cold water, whose roar is often to be heard underneath the glacier, issues forth from an icy cavern, and forces its way downwards through the boulders and shingle into the verdant valley below.

The structure and motion of glaciers, and effects of glacial action on the rock surfaces, have been studied by many naturalists during the last hundred years ; and the names of Charpentier, Agassiz, De Saussure, and James Forbes, will ever be inseparably connected with the subject of glacier motion.* To Forbes and Agassiz, how-

---

* J. D. Forbes, *Travels through the Alps*, (1843), also, *Norway and its Glaciers*, p. 234. (1853). The fact that the centre of a glacier moves faster than the sides was demonstrated by M. Agassiz, by experiments on the Glacier of the Aar, carried on about the same time as those of Forbes, and the results communicated to the *Academy of Science*, 29th Aug., 1842.

ever, science is indebted for determining the laws of glacier motion from observations, with mathematical instruments, taken amongst the Swiss Alps. Forbes' experiments were carried out on the Mer de Glace, above Chamounix, and the results arrived at may thus be summarised.

(1.) The motion of the highest part of a glacier is, on the whole, slower than that of the lower portion, but the motion of the middle region is slower than either. This only applies to certain glaciers like the Mer de Glace.

(2.) The central part of a glacier moves faster than the sides, and the surface faster than the bottom. When two glaciers unite, they act as a single one in this respect, just as two united rivers would do. Also, when a glacier bends, the line of quickest flow shifts towards the exterior angle of the valley, in which respect, also, the motion of a glacier resembles that of a river along a valley.

(3.) The difference of the motion of the centre and sides of a glacier varies :—

(*a.*) With the season of the year; and

(*b.*) At different parts of the glacier valley.

(4.) The rate of motion of a glacier varies with the period of the year and the temperature of the air, being faster in warm, and slower in cold, weather.

E.—Cause of Glacier Motion.

Various theories have been advanced to account for the motion of glaciers; but the knowledge that a glacier moves along its bed in a manner similar to that of a river inclines us to the belief that the motive force in each case is the same, namely, the force of gravitation. This observation applies essentially to those glaciers which move down the bottom of a valley; because, when ice is spread as a vast sheet over a nearly horizontal or undulating tract of country, there is reason for believing that another force than that of gravitation comes into operation, viz., that arising from the alternate melting and regelation of the glacier-ice itself. The dilatation theory of Charpentier, according to which a glacier is impelled by water percolating from the surface through fissures into the ice, and from time to time expanding while freezing, and thus forcing the glacier forward, has been recently advocated and developed by Dr. Croll.* The fact that glacier-ice is capable of moving over ridges or hillocks which obstruct its general course by a force from behind, or within the mass itself, leads to the con-

---

* Croll, *Climate and Time*, Chap. xxi., p. 514.

clus: n that occasionally some other force than that of
gravity comes into play. Perhaps we may be allowed to
conclude, that under special conditions, such as those of
an Alpine or Norwegian glacier valley, gravity is the
chief impelling force, while in cases where, owing to the
generally level character of the floor, gravity would be
ineffective, regelation and dilatation are the operative
agencies.* Passing, however, from this subject, we
proceed to consider the effects of glacier action, which
admit of no question.

F.—Effects of Glacier Action.

The effects produced by the motion of glacier-ice over
the surface of the land may be stated as follows :—

(1.) The polishing, grooving, and striation of
rock-surfaces.

(2.) The scooping out of hollows in the solid
rocks, which afterwards become rock-basins and the
beds of lakes.

(3.) The formation of moraines, and distribution
of erratics or boulder-stones.

---

* The question is very fully treated in Tyndall's *Glaciers of the Alps,* to which
the reader is referred.

(4.) The sculpturing of the rocks into mammilated forms known as *Rochés Moutonnées*, and perched blocks or boulders ; and

(5.) The formation of boulder-clay.

A brief account will now be given of these phenomena.

(1.) *The Polishing, Grooving and Striation of Rock-Surfaces.*

Notwithstanding that a section of a glacier, when first seen, presents the appearance of absolutely pure ice, it really contains some fine grains of sand and fragments of stone which have become firmly imbedded in its mass; and, as the glacier moves along, these substances, acting under great pressure, produce the effect of a planing and grinding machine, by which the bottom and sides of the valley, or hill-side, which have been subjected to glacial action, ultimately become ground down, striated, and grooved ; the striæ and grooves indicating the direction along which the ice has travelled. Surfaces of rock which have been subjected to this action, if protected by clay from weathering, often exhibit the effects with remarkable freshness, though thousands of years may have elapsed since the disappearance of the ice.

(2.) *The Formation of Hollows and Lake Basins.*

From a consideration of what has been said above, it will be inferred that glaciers possess the power, not only of grinding down prominences into smooth surfaces, but of hollowing basins in generally flat plains. Where a glacier debouches from a narrow valley on a plain, such as is formed by the Upper Rhone where it enters the plain of Geneva ; or where a glacier descends from the crest of a mountain on a comparatively level surface beneath, such as is inclosed by a " cirque " or " coomb," it will necessarily have the effect of grinding down the surface ; and a hollow will be formed which, on the retreat of the glacier, will become filled with water, and form a lake or mountain tarn. To such an origin Sir A. Ramsay has attributed the formation of many lakes and mountain tarns of Europe and the British Isles,[*] where the evidences are abundant and conclusive that the mountainous tracts were once the seat of snowfields and glaciers ; though, from the amelioration of the climate, the perennial snows have altogether disappeared. In another way, also, glaciers have been instrumental in forming lakes. The terminal moraines left on the melting away of the ice have ultimately become embankments, whereby the river waters have been dammed up and converted into

---

[*] Ramsay, *On the Glacial Origin of certain Lakes, &c.*, Quart. Jour. Geol. Soc., Vol. xviii. (1862). Also, *Phys. Geol. & Geog. of Gt. Britain*, Edit. 1878, p. 432.

lakes. Numerous examples of lakes of both kinds are to be found amongst the highland glens of England and Wales, Ireland and Scotland, as well as in other parts of the temperate regions of the world.

Sea-lochs.—Around the coast of the British Islands, but especially in Ireland and Scotland, are to be found inlets of the sea, with shallow bars or entrances, which deepen as we proceed up from the entrance towards the central parts. In such cases it will generally be found that the banks of the loch are more or less glaciated ; and there can be little doubt that the basin-shaped forms of such lochs owe their character to the same cause which has produced the rock-basins, now occurring as lakes. These sea-lochs are in fact true rock-basins occupied by sea-water, which passes in and out over a solid bar of rock, but slightly submerged, or possibly intertidal, as in the case of the Connel Falls at the entrance to L. Etive in Argyllshire, where a powerful flood of sea-water rushes inwards during the flow of the tide, and is succeeded by another with the opposite current during the ebb; each time with the roar of a cataract. On looking at the Admiralty map it will be seen that, as we proceed upwards from this intertidal bar, the depth of the loch increases to 76 fathoms above Aird Bay, forming altogether a curved trough, deepest near the centre, and gradually shallowing upwards and downwards. * Little Loch Broom presents

---

* For a map of this and other Scottish sea-lochs, consult Dr. James Geikie's *Great Ice Age,* p. 300.

another example, as does L. Long, L. Fyne, and L. Sunart. If the bar at the entrance to L. Lomond were but 20 feet lower, the waters of the sea would gain an entrance, and we should have ebb and flow of alternately salt, brackish and fresh water; while opposite Tarbet the bottom descends to a depth of 89 and ultimately of 105 fathoms. The banks, sides and beds of all these lochs afford ample evidence of glacial erosion; and we are justified in referring their basin-shaped conformation to this cause. In Ireland a similar, but less striking, example of a sea-loch is to be found in the case of Carlingford Bay, which at the entrance has a rock bar with only 4 fathoms of water at meantide, but higher up the loch the bottom descends to a depth of 16 fathoms. Another example will be found in the case of Killary Harbour, a narrow fiord-like arm of the sea, which stretches inwards from the Atlantic to the base of the Connemara Mountains. Near the entrance the maximum depth over the rocky bar is only 5 fathoms, but inwards the depth increases to 12 fathoms, and so continues for a long distance. Here again, all along the shore, the evidences of glacial action are most striking, the rocks being polished, striated and grooved in lines parallel to the channel. Other examples might be cited, but the above will probably be considered sufficient for the purpose of illustration.

(3.) *The Formation of Moraines.*

The formation of moraines has already been explained;

those of the sides constituting *lateral*, those of the centre, *medial*, and those of the lower end, *terminal*, varieties. Medial moraines originate at the point where glaciers of two valleys coalesce to form one, as in the case of the Glaciers de Lechaud and Du Géant at the foot of Mont Tacul, which give rise to the principal medial moraine of the Mer de Glace in Switzerland. As glaciers undergo periodic changes of dimensions, sometimes protruding far down the valleys, sometimes receding, successive terminal moraines may thus be formed; and where a glacier has altogether disappeared, its retreat is sometimes marked by successive terminal moraines thrown across the valley, indicating pauses in the course of final dissolution.

(4.) *The Sculpturing of Rocks.*

The sculpturing of rocks into mammilated forms has already been referred to. As the grinding process is necessarily most effective on the side of a projecting rock opposed to the course of the ice, this side is generally worn down to a smooth and polished surface, the other side often escaping the eroding action of the glacier. In this way forms of projecting rock surfaces called " crag and tail " are produced, from which the direction of the ice movement may be inferred. Numbers of such smooth rocks, cropping out along the mountain side from amongst the herbage, and having somewhat the appearance of a

flock of sheep, have given rise to the French term, *Rochés Moutonnées*, which is now applied to them exclusively. Transported blocks of rock are sometimes found perched on the edge of crags, and in other critical positions. These, from their composition, can be traced to their sources, and are often of such huge size as to make it impossible to refer their transport to any other agency than that of glacier ice. Enormous blocks of gneiss and granite from the Central Alps are thus to be found strewn on the flanks of the Jura hills above the Lake of Geneva; and they are very numerous in most parts of the British Isles, except the South of England.

(5.) *The Formation of Boulder Clay.*

Boulder clay (or *Moraine profonde*) consists of stiff clay containing stones and boulders, which are often glaciated. The clay is only occasionally laminated, and is of a reddish or blue colour; it often covers a surface of rock which has undergone erosion by ice. Boulder clay is considered to be a deposit which has been left by a glacier—or sheet of ice—after its disappearance, and it is found in many of the plains and valleys of the British Isles, and over extensive tracts of Northern Europe, which are believed to have been overspread by a great sheet of ice during the Glacial Epoch.*

---

* For an account of the mode of formation of boulder clay, the reader is referred to Prof. James Geikie's *Great Ice Age;* or Croll's *Climate and Time.*

G.—FORMATION OF ICEBERGS IN THE GREENLAND SEAS.

The floating islands of ice, which enter the North Atlantic through Davis Straits in early summer, and are often a cause of danger to ships crossing between America and Europe, have their origin chiefly in the vast snowfields and glaciers of Greenland. The whole interior of that great promontory is enshrouded in snow, and the glaciers which descend its valleys seawards, and which are sometimes over 2,400 feet in depth, are protruded into the waters of the ocean, sometimes to a distance of two miles ; and, ultimately, when the buoyancy of the ice has become sufficient to overcome the cohesion, sections break off from the main mass, and, rising majestically in the waters, float away, often turning over or bursting asunder with a noise like thunder. Dr. Sutherland, who witnessed these magnificient operations in 1852, states that in August of that year the whole coast southwards of Melville Bay, extending over a space 180 miles in length, and from 12 to 15 in breadth, was rendered perfectly unnavigable by reason of the number of icebergs floating in the waters. * The constant rise and fall of the tides exerts great power in detaching icebergs from their parent masses, as by this means a hinge-like action is set up as soon as the edge of the glacier comes within its influence, and is carried on even when the surface of the

---

* *Quart. Journ. Geol. Soc.*, Vol. ix., p. 305.

sea for many leagues is covered by a continuous sheet of ice. The mode in which icebergs are formed is illustrated by the ideal section (Plate XII). Enormous icebergs are annually sent off from the edge of the ice-sheet which covers the Antarctic continent.

H.—Former Extension of Glacial Conditions.

There is the clearest evidence that at a recently passed epoch the glacial conditions of the northern hemisphere were vastly more extensive than at the present day. Not only did the existing glaciers of the Alps, the Pyrenees, the Scandinavian Chain, the Caucasus, and of the Himalayas, descend far below and beyond their present limits, filling the now fertile valleys, and covering the adjoining plains with ice; but large portions of the British Isles were enveloped in perennial snow and ice, as were also the plains of North Germany, as far south as lat. 51° N. The same observation applies to a large area of North America and Canada. An immense sheet of ice and snow, moving southwards from the Arctic circle, debouched on the plains of North America, covering the region of the great lakes, and stretching as far south as lat. 38° to 40° N., where its terminal moraine has been traced for three thousand miles from the Atlantic sea-board.* From off these regions of the

---

* T. C. Chamberlain, *Third Report U.S. Geological Survey.*

PLATE XII.
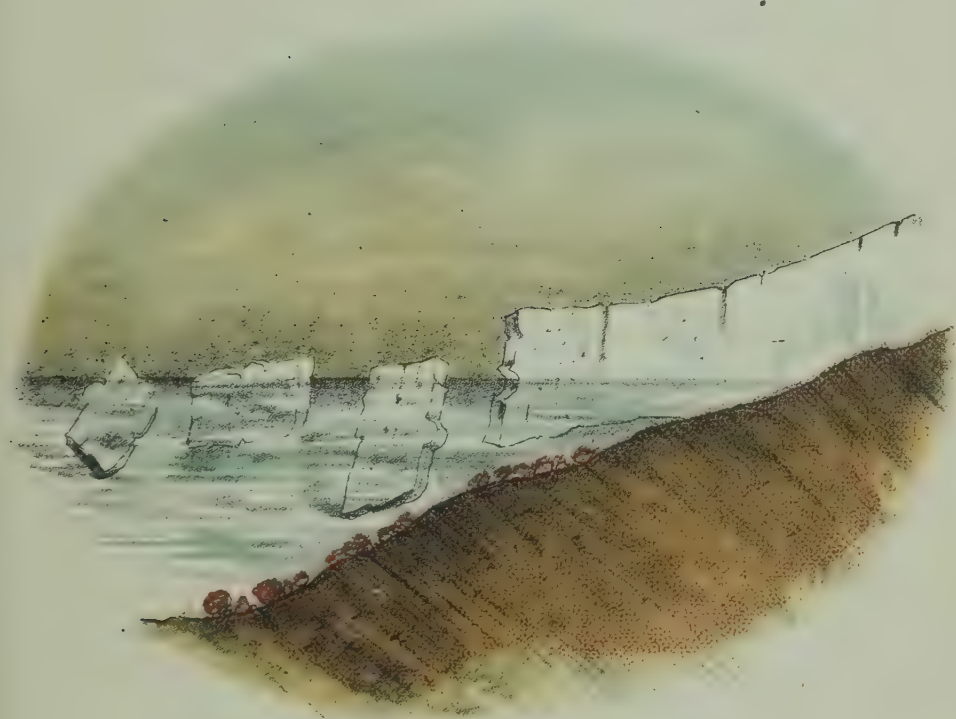
TO ILLUSTRATE THE FORMATION OF ICE-BERGS,
FROM A GLACIER IN THE GREENLAND SEAS.
(After Prestwich.)

northern hemisphere, the perennial ice and snow has now disappeared, except in very restricted mountain heights, and we can realize the extent of the change in climate which this change indicates. It is worthy of remark that, at the period referred to, the ice-sheet extended considerably further south in America than in Europe, corresponding to the range of the present annual mean temperature of both countries.*

I.—Hail.

The formation of hail has not yet been satisfactorily accounted for, but from the fact that it commonly accompanies thunderstorms, even in warm weather, and is attended by a sudden lowering of the temperature, we may infer that it is due to the sudden refrigeration of the air during electrical discharges. Hailstones are sometimes of large size, varying from the size of a pea to that of a hen's egg, and consist of compact masses of ice, generally angular in form, and, as hail usually occurs in summer at a time when vegetation is in full vigour, it causes much damage to plants and trees. Hail differs from snow in that the latter consists of water frozen into stellate crystals, variously modified, the former of solid amorphous ice. Numerous beautiful modifications of snow crystals have been noticed and described.

* A map showing the extent to which the British Isles were enveloped in glacial ice and snow will be found in my *Physical History of the British Isles* (1883), Plate xiii.; and another of the *World on Mercator's Projection*, showing its condition during the period of greatest cold, is given by Prof. Prestwich in *Geology*, Vol. ii., p. 468.

J.—WATERSPOUTS.

These meteoric bodies have been observed both by sea
and land, and are sometimes a source of danger to ships.
They consist of masses of vapour suspended in the lower
strata of the atmosphere, or hanging in columns from the
clouds, and endowed with a gyratory motion, sometimes
of sufficient strength to uproot trees, and cause destruc-
tion to buildings with which they happen to come into
contact.   During the formation of a waterspout, thunder
and lightning often occur, together with hail or rain ;
hence their connection with special electrical conditions of
the atmosphere cannot be doubted.   Waterspouts gene-
rally occur when the air is perfectly still.

When they take place at sea they present a remarkable
appearance, as the pillar of cloud appears to descend through
the atmosphere and meet another rising from the surface
of the waters ; but as the water has always been found to
be fresh, it has been assumed that the latter appearance
is deceptive.   As regards their origin, Kæmtz assumes
that they are due chiefly to two opposite winds, which
pass by the side of each other; or to a very high wind
which prevails in the higher regions of the atmosphere.
Peltier and many others ascribe to them, with more
probability, an electrical origin.*

* Ganot's *Physics*, by Atkinson, 12 Edit., p. 962.

CHAPTER XII.

UNDERGROUND WATERS AND SPRINGS.

A.—Percolation of Rain through the Strata.

In connection with the subjects of Rainfall and Rivers some observations on that of Springs are necessary. It is doubtless a very large one if dealt with in all its branches, and in any degree to a full extent. But without going much into detail, the leading facts regarding the percolation of underground waters, and their escape in the form of springs, may be placed before the reader.*

The rain which falls on the surface is disposed of severally and naturally in three ways :—

---

* Much information on this subject will be found in A. Daubrée's *Les Eaux Souterraines*, 3 Vols. (1887). Prestwich's *Geology*, Vol i. (1886). Sterry Hunt, *Chem. and Geol. Essays* (1879). *Reports of Committee, Brit. Assoc., on Underground Waters*, drawn up by C. E. De Rance. *Report of Royal Commission on Water Supply*.

(1.) A part of it passes off again into the air by evaporation ;

(2.) Part flows off the surfaces in streams ; and

(3.) Part enters the soil, and, percolating downwards through the pores and fissures of the rocks which form the crust of the earth, either remains locked up in them, or finds its way out into the air in the form of springs.

The relative proportions of the rainfall thus disposed of depend on several conditions; as, for example, the temperature and humidity of the air, and the porosity of the soil and strata. If the temperature be low, and the air nearly saturated with moisture at the time of rainfall, little of that rainfall will be lost by evaporation ; nearly the whole being used up by percolation, or passing off in streams. On the other hand, if the temperature be high, the air tolerably "dry," and the soil highly impervious, nearly the whole will pass off by evaporation and by surface streams.

B.—Permeable and Impervious Strata.

Some rocks and strata are much more pervious to rain than others. Amongst the more pervious varieties are

sand, sandstone and conglomerate, limestone (especially chalky strata), and various kinds of porous volcanic rocks. Slaty and gritty strata, such as those of Silurian age, probably depend for their permeability on the amount of fissuring to which they have been subjected ; while stiff clays and shales are only very slightly permeable, or absolutely impervious to water. Owing to these qualities, the Old Red Sandstone, the Triassic sandstones, some beds of Millstone grit, the Jurassic limestones, the Lower Greensand and Chalk formations, constitute the more important water-bearing formations of the British Isles.

The following are some examples showing the proportion of water which various rocks are capable of absorbing :—

	Water of saturation per cubic foot.
Thanet Sand (fine, slightly argillaceous) ·	2·80 gallons.
Lower Greensand (very coarse) .	2·18 ,,
Chalk	2·0 ,,
Oolitic limestone* . . .	1·50 ,,
Magnesian Limestone* . .	1·02 ,,
Millstone Grit (Bristol)* . .	0·06 ,,
,, ,, (Sheffield)* . .	0·47 ,,
Old Red Sandstone (Gloucestershire)*.	0·72 ,,

* E. Wethered, *Rep. Brit. Assoc., On Underground Waters* (1882). The results in the case of the Greensand and Chalk are by Prof. Prestwich.

Sandstone absorbs from 2·2—2·7, and for very porous varieties, 6·9—9·3 per cent. of its volume. If we take as a mean 2·5 per cent. for the volume of water which a sandstone formation, such as the Potsdam sandstone of America, is capable of absorbing, we find that with a thickness of 100 feet the formation would contain, in every square mile, in round numbers, 70,000,000 cubic feet of water.* With this result it is not surprising that some sandstone formations, such as the New Red Sandstone of England, are found capable of supplying more than one million gallons per day of water when penetrated by deep wells. It is to be recollected, however, that as Professor Prestwich has pointed out, the quantity of water available for supply from wells must be regarded as distinct from that which the rock can imbibe. The one is the portion which the rock holds until it is lost by evaporation, or driven off by heat; while the other is that which passes more or less freely through the strata.

C.—Proportion of Rainfall absorbed by Strata.

During the six months of the year when precipitation of rain is greatest and evaporation least, the amount of water which porous formations are capable of absorbing is enormous. The chalk of the London Basin is one of

---

* Dr. Sterry Hunt, *Chemical and Geological Essays* (Edit. 1879). Mr. Wilkinson has found that the Irish sandstones are capable of absorbing from one to eleven pounds of water per cubic foot. *Pract. Geol. and Archit. of Ireland. Tables of Experiments.*

these. Taking the rainfall for the six months at 16·42 inches, and deducting 2·5 inches for saturation and evaporation, we have 13·92 inches as the amount which actually penetrates the strata, and becomes a source of supply. Now, each inch of water gives 39,666 gallons per square mile per day, and taking an area of 1,025 square miles as the area of the chalk formation, extending up the Thames valley as far as Twyford, and lying on either side, and as far down as the meridian of the Medway at Sheerness, we find that the quantity of water available for supply, including that given off by springs, amounts in round numbers to 609,000,000 gallons per diem.*

D.—Increase of Temperature received by Underground Waters.

Owing to the increase of temperature on descending into the crust from the surface, waters which percolate downwards through the fissures become warm, and assume the temperature of the strata necessarily, and when the depth is sufficient approach that of boiling point; this would be reached at a depth of about 10,000 feet; but as the pressure is so much increased, actual boiling (that is giving off bubbles of vapour from within the mass) could

---

* Experiments by Mr. J. Roberts on blocks of New Red Sandstone, show that it is capable of absorbing 0·733 gallons of water for each cubic foot; and that the water passed through a cubic foot in 18 hours. *Rep. Brit. Assoc.* (Sections C. and G.) 1878.

not take place at that depth. To enable water to boil under the ordinary pressure of the atmosphere, a temperature of 212° Fahr. is necessary ; owing, however, to the elasticity of steam increasing more rapidly than the temperature, a depth would ultimately be reached at which steam would be formed within the interior of the earth, and would force its way into any cavities or fissures within its reach.*

E.—Origin of Saline Springs.

As water percolates through the strata, it necessarily takes up the soluble materials with which it comes in contact, which are extremely varied, and often abundant. The greater number of springs contain certain proportions of carbonate of lime, sulphate of soda, sulphate of lime, magnesia, or iron, chloride of sodium, and this last often in such large quantity as to produce brine. Again, water which percolates through strata throwing off carbonic acid in quantity, becomes highly charged with this gas, and thereby becomes carbonated water. The temperature of water exerts no influence on the properties of the salts dissolved in it, and comparatively little on the quantity of them that is taken up. The Carlsbad " Sprudel," at a

---

* It may be mentioned in this connection, that granitic rocks contain saline water, occurring in numerous minute cavities in the silica or quartz. This fluid belongs to the period of the original formation of the rock.

temperature of 167° Fahr., and the Nauheim spring at 86° Fahr., bring up large quantities of carbonic acid. Brine springs, derived from water which has come in contact with beds of rock-salt, are numerous, both in England and the Continent: they occur in Cheshire, Staffordshire, Cheltenham, and Worcestershire, and have been reached by borings at Rugby, Stafford and Middlesborough.

Some of the saline waters found in Coal mines, as in the case of those of Ashby-de-la-Zouch, may be supposed to have been retained in the strata through long geological ages.* In North America saline springs and wells are numerous. Those from the Trenton Limestone and Medina Sandstone at Whitby, Hallowell, and St. Catherine, are impregnated with chlorides of sodium, calcium, and magnesium, together with minute traces of iodides and bromides; and Dr. Sterry Hunt has arrived at the conclusion that, in some cases, these waters have been locked up in the strata from the period when the latter were deposited in the Palæozoic seas.†

---

* An analysis of this water from the Moira Colliery, by Dr. Ure, gave the following results:—One Imperial Gallon contained,

						GRAINS.
Chloride of Sodium	..	..	..	..	..	3,700.7
Chloride of Calcium	..	..	..	..	..	851.2
Chloride of Magnesium	..	..	..	..	...	16.0
Bromides of Potassium and Magnesium			..	..		8.0
Protochloride of Iron	..	..	..	..	..	trace.
				Total	..	4,575.9

The above is taken from Mammatt's *Geological Facts*, p. 35, (1836.)

† *Chemistry of Natural Waters; Chem. and Geol. Essays*, Chap. ix. and x.

F.—Hot Springs.

Except in volcanic districts where the waters derived
from underground sources may have come in contact with
lava at a high temperature, the occurrence of hot springs
may be accounted for by supposing that the waters perco-
late through strata seated at considerable depths below the
surface, and have, consequently, passed outwards towards
the ground with a temperature belonging to the strata
themselves. Such springs are found in nearly all parts
of the world, including districts entirely destitute of
modern volcanic rocks, such as Bath ; but underground
waters which flow along fissures having the form of an
inverted syphon may issue forth at the surfaces consider-
ably cooler than during a part of their course at greater
depths. I shall offer a few illustrations of hot springs
derived both from volcanic and non-volcanic sources.

(1.) *Volcanic Springs.*

Hot springs, accompanied by jets of steam, are abun-
dant in Iceland, New Zealand, and the Yellowstone
region of Western America ; all these derive their high
temperature from highly heated volcanic rocks, though
active volcanic action may have ceased, or become dor-
mant. In Iceland, in some districts such springs abound.
Here are seen oval basins, and large natural tanks,

formed of siliceous tufa, from which hot water is quietly flowing ; in other places there are round funnels of wonderful regularity, from which hot water is spouting up; while, again, it shoots up from little crater-like cones formed of siliceous-sinter, or palagonite. The grandest of all these are the Great Geyser and the Strokkr, so well-known and often described that repetition is unnecessary here ; and not less remarkable are those of the National Park, in the territory of Wyoming, in North America.

Hot springs, accompanied by steam jets, occur in the Lagoons of Tuscany, on the islands of Ischia, Lipari, and Pantellaria ; at Baiæ and at St. Germano, near Naples ; they are also found at Teneriffe and Jorullo, in Mexico, besides the countries mentioned above. It is possible that some of the hot springs of Palestine and the Jordan Valley may derive, at least, a portion of their heat from partially heated volcanic rocks. Of these the most remarkable are the Zerka Ma'in (or Callirhoë), which enters the Dead Sea from the east with a temperature of 130° Fahr., and the Hammam springs, near the Sea of Tiberias, with a temperature of 143.3° Fahr.[*] In order to account for those of an intermittent character, we may suppose, with Bunsen, that there are underground hollows into which water and steam find their way. As the temperature increases the elastic force of the steam,

[*] Tristram *Land of Moab*, (1873). Lartet, *Voyage d'Exploration de la Mer Morte*, (1874). Hull, *Geol. of Arabia Petræa and Palestine, Memoirs Palestine Exploration Society*, (1886), p. 22.

increasing in a still greater ratio, ultimately acquires such force that the water is driven out of the internal chamber into the funnel, through which it ascends into the air.

(2.) *Non-Volcanic Springs.*

Amongst the best-known hot springs, which are certainly independent of volcanic action, are those of Bath in the West of England. Here there are three springs of saline and alkaline waters, with a temperature from 112° to 116° Fahr. The dissolved materials consist of chlorides of sodium, magnesium, sulphates of potash, soda and lime, and carbonate of lime, together with large quantities of nitrogen and carbonic acid gas; and the quantity of water issuing forth leads to the conclusion that the gathering ground must be considerable. The existence of the Bath thermal springs is accounted for in this way. The City of Bath lies in the narrow valley of the Avon, amongst the Jurassic limestone hills, and is built on the Lias formation. Below the Lias are Triassic strata, and below these Carboniferous, in unconformable sequence. Some miles to the south, the Mendip hills, formed chiefly of Carboniferous limestone, rise to a higher level, and Sir C. Lyell believed that the waters from these hills descending with the limestone strata which are highly cavernous, below the position of Bath, ultimately force their way to the surface by hydrostatic pressure, and with a temperature due to the depth to which they had descended.

Amongst the Continental hot wells of the non-volcanic class, are those of Wiesbaden, with a temperature of 70° Cent. (158° Fahr.) ; Baden-Baden, at 67° Cent. (153° Fahr.); Carlsbad ("Sprudel"), at 75° Cent. (167° Fahr.) ; of Lavey, in the Canton of Vaud, at 45° Cent. (113° Fahr.) ; of St. Gervais, in Savoy, at 41·25° Cent. (106·25° Fahr.) ; the Aigues-Chaudes, in Cantal, in France, at 87° Cent. (189·5° Fahr.) ; Vichy, with one spring at 45° Cent. (113° Fahr.) ; and the Kaiserquelle at Ofen, at 61° Cent. (141° Fahr.). According to Daubrée, the hot springs of Baden-Baden, as also those of Erlenbad, Saeckingen, and of Royat in Auvergne, issue forth along well-marked lines of faulting, by which formations of different kinds and ages are brought into contact. * To the above we may add the remarkable warm springs of " Ain es Sultan," in the valley of the Jordan near Jericho, with a temperature of 71° Fahr. The high temperature of some other springs in this valley, may (as already intimated) be due to former volcanic action.

* Daubrée, *Les Eaux souterraines*, t. i., p. 173.

CHAPTER XIII.

ARTESIAN WELLS AND UNDERGROUND
WATERS.

A.—Conditions under which they occur.

When rain falls upon porous strata, that part of it which
enters the ground gradually sinks down until it is retained
by some impermeable stratum, or is unable to penetrate
further, owing to the increased density of the rock itself,
due to pressure.   Where this latter factor does not come
into operation the waters form underground reservoirs,
the upper surface of which is generally curved either
upwards or downwards according to circumstances.
Thus, in the case of the waters of the Chalk formation
which naturally find an outlet by springs along the
margin of river valleys, or at the junction with the almost
impervious " chalk-marl " along the borders of the
terminal escarpments, the surface of the underground
reservoir slopes upwards with the ground, and wells, in
order to obtain a supply of water, have to penetrate

Fig. 8.—Section through the Chalk Downs of Berks. and Wilts., to show position of Springs and Water-bearing Strata.
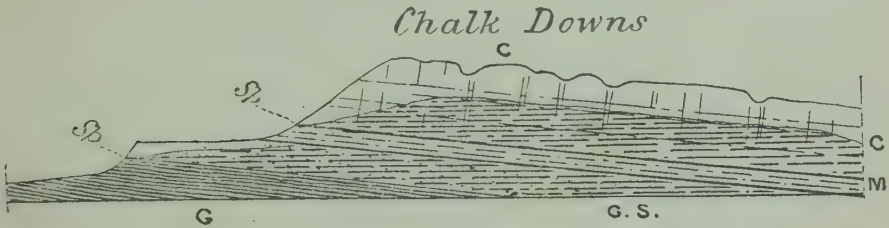
C.—The Chalk Formation. The unshaded portion being above the surface of the underground reservoir, represented by the portion shaded with horizontal broken lines.

M.—The nearly impermeable strata called " chalk-marl " giving rise to springs at Sp.

G.S.—Upper Greensand, water-bearing, and resting on the impervious Gault-clay (G), giving origin to a second series of springs (Sp).

downwards, through nearly dry strata, to the surface of the subterranean basin. This will be more readily understood by reference to the figure (Fig. 8).

On the other hand, when the permeable strata dip downwards from the outcrop, forming both a superficial and geological basin or trough, the surface of the underground reservoir slopes downwards, as the resistance of the planes of bedding to transgressive percolation, obliges the water to percolate more or less in a direction coincident with these planes. The lower strata

of water in such cases occur under hydrostatic pres-
sure, consequent on the relative levels of the gathering
ground and the centre of the basin; and wells or
bore-holes put down in the central parts of such

FIG. 9.—SHOWING STRUCTURE OF GROUND NEAR TRENTHAM,
STAFFORDSHIRE, AND POSITION OF BOREHOLE WITH
FOUNTAIN OF WATER.
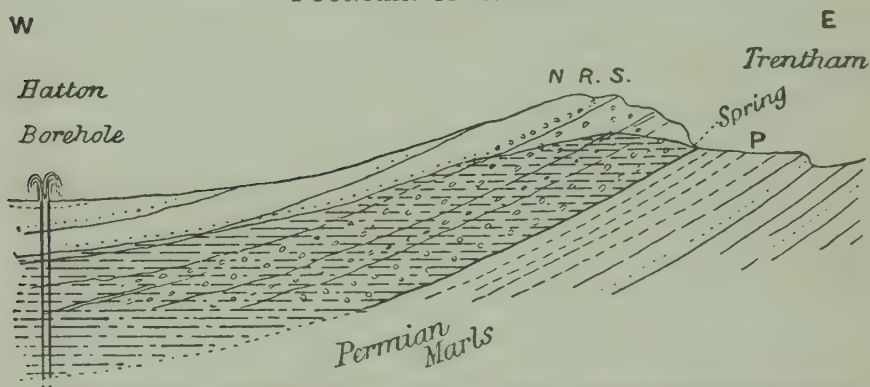
N.R.S.—A ridge of New Red Sandstone and Conglomerate,
highly permeable and water-bearing, resting on nearly im-
pervious strata of marl belonging to the Permian formation.
The position of the underground reservoir is shown by the
horizontal broken lines; and the bore-hole at Hatton, having
penetrated deep into the water-bearing strata, the water rises
above the surface by hydrostatic pressure.

basins release the waters, and admit of their rising up-
wards through the strata, and if the pressure be sufficient,
of spouting in a column above the surface of the ground,
as represented in figure adjoining (Fig. 9).

The conditions under which artesian wells may be formed are well illustrated by the geological structure of the London Tertiary Basin (Fig. 10). They consist essentially of a permeable formation (like the Chalk), overlain by another that is impervious (like the London Clay), and both arranged in the form of a geological basin or trough. In such a case the rainwater, percolating down-

FIG. 10.—SECTION THROUGH THE LONDON BASIN.
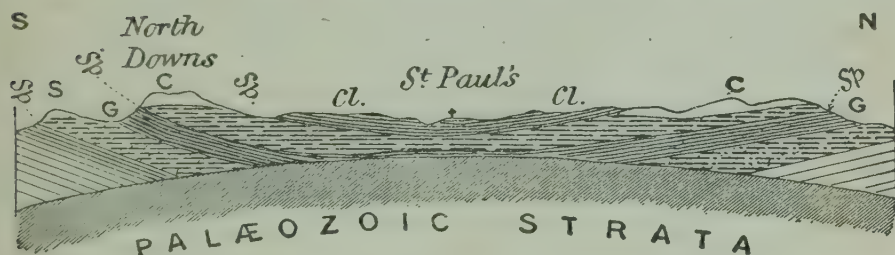
Cl.—London Clay, &c. (Lower Tertiary Strata).

C.—Chalk-formation; the water-bearing portion being shown by the horizontal broken lines.

G.—The Gault Clay formation; impervious.

S.—The Lower Green Sand; water-bearing and giving rise to springs (Sp.).

wards into the permeable beds, and flowing in the direction of the centre of the basin, is retained at hydrostatic pressure by the superincumbent impervious beds, and is unable to escape in a vertical direction till released by a shaft or well sunk from the surface. Naturally, the pent-

up waters find an outlet in springs (Sp.) which break out at the surface along the margin of the upper impermeable beds (which is the level of saturation), as is the case along the line of junction of the Chalk and London Clay to the south of the Thames Valley. Somewhat similar conditions of alternating permeable and impervious strata, concentrically arranged, give rise to springs, and admit of artesian wells in the Paris basin.*

* Daubrée, *loc cit.*, T. i., p. 81.

CHAPTER XIV.

OTHER CONDITIONS OF TEMPERATURE OF WATER.

A.—Formation of Ground-Ice.

At the commencement of a frost we often find the bottom of a river of no great depth coated by ground-ice, the mode of formation of which is not very clearly understood. The formation is thus accounted for by Buff.[*] Since ice is lighter than water (its specific gravity being 0.916) one would expect that it could only appear at the surface; nevertheless, it is often found at the bottom of rivers, especially in such countries as Canada, where it is known as " anchor ice." Now the growth of ice, like that of any other crystalline substance, is very much promoted by the presence of a solid nucleus, as of a crystal already formed, or of a particle of solid matter.

---

[*] Buff, *loc. cit.* p. 171.

Ice is never formed from the middle of a basin of water, but always starts from the sides and goes on growing towards the centre; but if a piece of ice be hung in the midst of some freezing water, it will forthwith grow in size by the addition of fresh ice. If there be no such solid particles present, the temperature of the water may be lowered below 32° Fahr. (0° Cent) before it begins to solidify. At the commencement of frost the water of a stream, being cooled down below freezing point, is forced in the course of its current to the bottom, and here first meeting with some solid substance gives rise to the first formation of ice on the bottom. The ground-ice by continued additions increases its growth, till, at length, being lighter than water, it rises by its buoyancy to the surface, carrying with it mud, stones, &c., which thus betray its origin. In stagnant water ground-ice is never found.

B.—Temperature of Water in Deep Lakes.

At the bottom of deep lakes the temperature is unchanged from year to year, being generally above 39.2° Fahr. (4° C.)—the point of maximum density of water, but seldom or never lower; and since this is the temperature of maximum density it is impossible that deep stagnant water should be cooled down below it, because as the water is cooled down to this point at the surface it descends, layer by layer, and is replaced by warmer masses.

In the Lake of Geneva, the effect of the changes of external temperature have been traced to a depth of 240 feet ; from this depth downwards to that of nearly 1000 feet an unvarying temperature of 34.9° Fahr. (6.6° Cent.) prevails. In the Lake of Constance a constant temperature of 40.1° Fahr. (4.5° Cent.) prevails in the deeper parts, and in that of Neuchâtel of 41° Fahr. (5° Cent.) prevails. The slight excesses in some cases are probably attributable to the heat of the bottom.

CHAPTER XV.

TERRESTRIAL MAGNETISM.

A.—Historical Sketch.

The attractive power exerted by a natural magnet, or lodestone,* on small pieces of iron seems to have been recognized from remote antiquity. It is referred to by Homer, Pythagoras and Aristotle, and at a later date by Pliny. The Chinese are credited with the invention of the magnetic needle, and the mariner's compass was certainly known in the 13th century, if not earlier, as Dr. Gilbert affirms that Paulus Venetus brought this instrument from China into Italy in 1260. When Columbus set sail on his Voyage of Discovery, after leaving the European waters, the sailors discovered that the magnetic needle varied from its direction towards the Pole Star,

---

* The name for magnetic iron-ore, or magnetite; which crystallizes in the monometric system, and has the chemical composition $Fe_3 O_4$.

the variation increasing daily as they proceeded westward. It seemed to them as if the laws of nature were changing as they receded from the old world, and that they would be bereft of this guide as they traversed the vast and trackless ocean before them. Thus they were filled with dismay, and Columbus had to task his powers of invention for reasons wherewith to allay their terrors. He told them that the direction of the needle was not towards the Pole Star, but to some fixed and invisible point. The variation, therefore, was not caused by any fallacy of the compass, but by the movement of the North Star itself, which, like other heavenly bodies, had its changes and revolutions, and every day described a circle round the Pole.* It was not, however, till about the middle of the sixteenth century, that accurate observations were made on the variation of the needle. In 1541 it was found that the variation (or declination) of the needle from the meridian of Paris was about 7°—8° easterly; in 1550, it was 8°—9°; and in 1580 it was 11½°.

The discovery of the dip (or inclination) of the needle was made in 1576, by an instrument maker, Robert Norman. Having constructed needles which he always balanced on a pivot before touching them with a magnet, he found that after they were magnetized the north point declined below the horizon. In 1650 Bond pub-

---

* Washington Irvine, *Life and Voyage of Columbus*, Vol. i., p. 167 (Edit., 1880).

lished a treatise on navigation called *The Seaman's Calendar*, in which he maintained that he had discovered the true progress of deviation of the compass ; and subsequently published a table of computed variations for many years, which agreed very closely with those actually observed as far as about 1690, but afterwards varied considerably. In 1672 Dr. Halley commenced his investigations on Terrestrial Magnetism, and in 1683 published his *Theory of Magnetism*, which, to a certain extent, forms the basis of more modern researches on this subject. In 1722 Graham discovered the remarkable phenomenon of the daily variation of the needle. Between the 6th February and 12th of May of that year, he made a thousand observations in the same place, from which he found that the amount of the daily variation was 55′ ; that is to say, between 14° 45′ and 13° 50′ west. In 1700 Halley published a sea-chart, on which he had traced the lines of variation of the compass over all parts of the globe—based on an immense number of observations which he had collected and systematized. These lines were drawn at intervals of five degrees of variation, and were the first graphic representation of the phenomena of magnetic variation over the globe. Owing to the rapid changes in the variation, as well as inaccuracies in the original methods of observation, the chart afterwards fell out of use. Similar charts have since been constructed by Humboldt, whose contributions to the science of terrestrial magnetism were of great value, by Sir Edward

Sabine, Dr. H. Lloyd, and others. The most recent chart for the British Isles is that constructed from their own observations by Professors Rücker and Thorpe. Sabine's contributions to the subject of terrestrial magnetism are of the highest value, and are on a most extensive scale ; but there have been for years past many distinguished workers in this field of natural science all over the globe, including amongst their numbers the names of Lenz and Biot.[*]

B.—Three Classes of Phenomena or Magnetic Elements.

We now proceed to consider more in detail the three groups or elements into which all the complex phenomena of terrestrial magnetism may be resolved. These are:—

(1.) The Variation, or Declination, of the Magnetic Needle.

(2.) The Inclination, or Dip, of the Needle.

(3.) The Intensity of Terrestrial Magnetism.

---

[*] Sabine's most important papers are to be found in *The Philosophical Transactions* for the years 1840 to 1849, and *Brit. Assoc. Report*, 1837, with charts showing the distribution of magnetic intensities over the earth's surface.

All the above classes of phenomena are capable of being represented by lines traced on a map or globe ; but, as Sir E. Sabine has observed, in considering their comparative fitness for promoting a knowledge of terrestrial magnetism, the Lines of Equal Intensity have in one leading respect an advantage over the other two.[*] Viewed under the most favourable circumstances, the magnetism of the earth is a highly complicated subject, and needs not the additional complication of having its phenomena mixed up with considerations foreign to itself. Now, the Lines of Equal Dip and Equal Variation do not express simple magnetic relations. The lines of Equal Dip, for example, connect those stations on the earth's surface where the direction of the magnetic attraction forms a certain angle with the horizontal plane at the station. But every station has its own horizontal plane depending on the direction of gravity (See *ante*, p. 85), which has no necessary connection with magnetism. As the zero planes thus differ, the equality of Dip does not express, or necessarily imply, a simple magnetic relation, but has reference to the attraction of gravitation, as well as to that of magnetism. The Lines of Equal Variation express a complex relation of a similar kind ; here, also, the zero planes change with the station. It is otherwise, however, with the Lines of Equal Intensity. Whatever may be the sources of magnetic attraction, and wherever their situa-

---

[*] Sabine, *Brit. Assoc. Report*, 1837, p. 63.

tion in space—whether on the earth's surface, or above or beneath it—the Lines of Equal Intensity express the equality of their resultant at all those points of the earth's surface through which they are drawn, unmixed with any considerations foreign to magnetism. They are pure magnetical isodynamic lines at the surface of the globe; and the instruction they convey is, therefore, more simple, direct and unequivocal than in the case of the other two. In a word, the Lines of Equal Intensity are better suited to convey to the mind a view of the distribution of magnetic forces over the globe than any others which can be drawn.

C.—Variation or Declination of the Magnetic Needle.

The declination of the magnetic needle is the angular distance between . the magnetic meridian and the geographical meridian of the place. The magnetic meridian is a vertical plane passing along the axis of the magnetic needle when freely suspended on a central pivot, and not influenced by surrounding objects. This meridian is coincident with the direction of the earth's magnetic force at that place. If we trace on a map a series of lines connecting the spots having the same declination, called "Isogonic Lines," we then have a Declination chart showing at each spot over the globe the direction and amount of the variation of the magnetic

needle. A chart showing these lines over the region of the British Isles is here given (*See* Plate XIII.). Of the lines on this chart, there are two of special importance ; these are the *Lines of No Declination*, along which the magnetic meridian coincides with the geographical. Of these, the western at the present day traverses the Continent of America and the Atlantic Ocean in a direction from north-west to south-east. Commencing in the Polar Sea, in about 100° West Longtitude, its course has been traced through Hudson's Bay and Lake Ontario until it leaves the North American Continent near Cape Hatteras about 75° West Longitude. It then traverses a part of the Atlantic Ocean to the east of the West Indian Islands until it meets the Continent of South America, near the mouth of the Amazon, in about 50° West Longitude. Proceeding thence in a south-easterly direction, it cuts the shores of the Continent again near to Rio Janeiro, and enters the South Atlantic, where it pursues the same direction as before.

FIG. 11.—TO SHOW THE MAGNETIC DECLINATION. N.S., TRUE NORTH AND SOUTH ; *n.s.*, THE MAGNETIC NORTH AND SOUTH AS SHOWN BY THE NEEDLE BALANCED ON ITS PIVOT C. N.C.*n.*, THE ANGLE OF DECLINATION.

PLATE XIII.

CHART
OF THE
BRITISH ISLES.
WITH LINES OF
EQUAL
MAGNETIC VARIATION
OR
ISOGONIC LINES
FOR THE YEAR
1888.
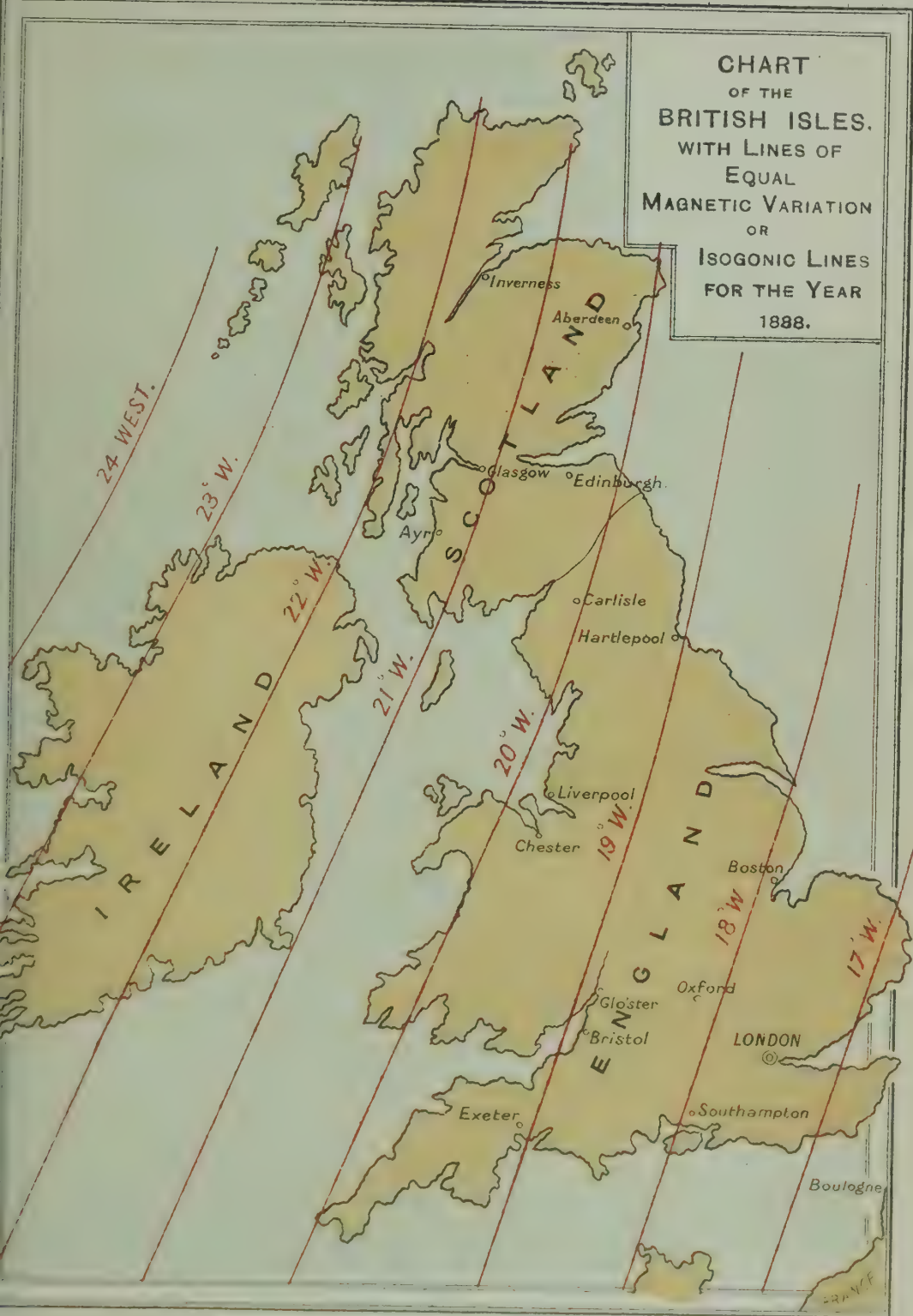
The eastern line of *No Declination* follows, at present, a somewhat similar direction. It traverses European Russia from the White Sea to the Caspian, and enters the Indian Ocean in about 65° E. long. It then pursues the same general direction in the Indian Ocean, as far as about 8° S. lat., where it takes a sudden bend to the east, and follows the parallel of 10° S. lat. from 90° to 12° E. long. At this point it again bends southwards, and intersecting the coast of Australia in about 125° E. long., crosses that continental island in a southerly direction, and enters the southern ocean at about 130° E. long. In the space between these two lines, that is, to the east of the former and west of the latter, the declination is *Westerly*. This space includes the eastern parts of America, the Atlantic Ocean, nearly the whole of Europe, and the whole of Africa. In the remaining division of the globe, which includes the Pacific Ocean and the greater part of Asia and of America, the declination is *Easterly*. There occurs, however, in the eastern part of Asia and the adjoining sea, *a Closed Curve of No Declination*, within which the declination is again westerly. This remarkable loop, enclosing part of Siberia and of the Chinese Empire, has the form of an oval, whose greater axis lies nearly in the meredian of 130° E. long. The diameter of the oval extends from about 20° to 70° N. lat.*

---

* Lloyd, *Treatise on Magnetism*, p. 104; also Ferguson's *Electricity*, Prof Blyth's Edit. (1882).

D.—Magnetic Poles.

From the form of the Lines of Equal Declination Halley inferred that the earth has four Magnetic Poles, two in each hemisphere—a stronger and a weaker. The position of these poles, as deduced by Professor Hansteen, are as follows :—

	Lat.	Long.
Stronger (or American) North Pole	70° 5'N.	99° 6 W.
Weaker (or Siberian) North Pole	85° 21'N.	118° 39'E.
Stronger ... ... South Pole	69° 26'S.	138° 35'E.
Weaker ... ... South Pole	77° 17'S.	120° 57'W.

E.—Duperrey's Lines.

The most natural, as well as the most instructive, mode of grouping graphically the observed results, seems to be that adopted by Captain Duperrey in charts published in 1836. The curves of Duperrey indicate, not the deviation of the needle from the true north at each place, but its actual direction. The "magnetic meridians" of Duperrey are curves traced on the globe, to which the direction of the freely-suspended horizontal needle is everywhere a tangent. At each point, therefore, the direction of the curve is that of the magnetic meridian of the place. These meridians converge towards two points—one in the northern, the other in the

southern hemisphere. They do not, however, all meet at the same point; but the successive intersections of each pair of contiguous meridians form a closed curve, the central points of which may be denominated " magnetic poles." The north magnetic pole so defined is nearly in 70° N. lat., and 98° W. long. The south magnetic pole occurs to the south of Australia in lat. 75° S., and 138° E. long. nearly.*

F.—Variations in Time of the Magnetic Needle.

These may be arranged under three heads, viz. :—

>   (1.) Secular;

>   (2.) Annual; and

>   (3.) Diurnal Variations.

(1.) *Secular Variation.*

The Secular Variation, or Declination, varies from place to place, and from time to time, but very slowly. In Great Britain, observations tend to show that the needle has been pointing more and more towards the west during a lengthened period, but since 1815 has begun to return eastwards. This implies either that there was an increase of power of the American, as compared with

---

* Lloyd, *loc. cit.*, p. 105.

the Siberian, Focus, or a motion of the Siberian Focus westwards down to the period above stated. The Declination at Greenwich is now a little over 18°, and at Edinburgh 22°. In 1815 the westerly variation was at its maximum in London, being 24° 27′; in 1865, it had fallen to 21° 6′; and in 1887 it was as above.

(2.) *Annual Variation.*

Annual Variation or Declination was first discovered by Cassini in 1780. In Paris and London it is greatest about the vernal equinox, diminishing from that time to the summer solstice, and increasing again during the nine following months; it does not exceed 15′ to 18′.

(3.) *Diurnal Variation.*

Diurnal Variations were first discovered by Graham, in 1722. They can only be observed by means of long needles or delicate indicators, such as the reflection of a ray of light. In this country, the North Pole moves every day from east to west from sunrise until one or two o'clock, it then tends towards the east, and at about ten o'clock regains its original position. During the night the needle is almost stationary. Thus the westerly declination is greatest during the warmest part of the day.

A still more striking connection between the sun and the fluctuations of terrestrial magnetism was discovered

in 1852 by Sir E. Sabine, who had noticed that every eleven years the amount of the diurnal variations was larger than at other times. For forty years, a German astronomer, Schwabe, had been observing the variations of sun spots on the surface of the sun, and had found their frequency subject to an average period of about eleven years. Sabine noticed that the two eleven yearly periods were coincident; that is to say, the years of many sun spots were also the years of large daily variation of the magnetic needle, and *vice versâ*. This important observation has been fully confirmed by subsequent investigations, and Balfour Stewart has traced a similar periodicity in the recurrence of auroræ and of other meteorological phenomena. But, in addition to these regular variations of the magnetic needle, there are also irregular variations or perturbations. A sudden *magnetic storm*, as it is called, will break out and affect the compass needle over a considerable area of the earth's surface. These magnetic storms are accompanied by electrical disturbances in the earth, and frequently powerful earth currents and auroral displays will simultaneously occur with the magnetic storm; but which is the cause and which the effect, is not yet known; or whether, as it is more likely, both are due to a common cause outside the earth. The photographic records of the magnetic variations, called " Magnetographs," which are now being made at different places over the earth, will eventually, it is hoped, throw much light on the difficult subject of the meteorology of the earth and air.

G.—Inclination or Dip.

The angle which the axis of a magnetic needle makes with the horizon is called the Dip or Inclination. The Inclination, like the Declination, varies from time to time, and has been decreasing in London for over a century, as shown by the following table [*]:—

Year.	Declination.	Inclination.	Horizontal Force.
1720	—	74° 42′	—
1780	—	72° 8′	—
1800	—	70° 35′	—
38	—	69° 38′	—
50	—	68° 48′	—
65	20° 59′	68° 9′	3·829
75	19° 41′	67° 47′	3·885
77	19° 22′	67° 45′	3·891
78	19° 14′	67° 44′	3·895
79	19° 6′	67° 42′	3·900
80	18° 59′	67° 42′	3·899
81	18° 50′	67° 41′	3·903
82	18° 45′	67° 41′	3·904
83	18° 41′	67° 41′	3·909
84	18° 32′	67° 39′	3·916
85	18° 26′	67° 38′	3·917
86	17° 54′	67° 27′	3·918

[*] Fergusson, *loc. cit.*, p. 53.

H.—CHART OF ISOCLINAL LINES.

Lines traced on a map of the earth connecting points of equal inclination exhibit graphically the arrangements which they take, and it will be found that they resemble closely the magnetic parallels above referred to. Within the tropics they are slightly inclined to the equator. The flexures increase with the latitude, and in the higher latitudes they tend to form closed curves encompassing the points at which the inclination is 90°, or those wherein the needle assumes the vertical position; to these points the name "Magnetic Pole," or "Pole of Verticity," is ordinarily given.* These do not exactly coincide with the foci of maximum intensity.

From observations of the dip, we find that it has been gradually decreasing for the last century and a half. The annual rate of decrease is at present about 2·6′. From the time observations have been taken of the declination and dip until now, we are far from having completed a cycle of change of either, and it is a matter of speculation how long it may take to complete such a cycle.

---

* Lloyd, *loc. cit.*, p. 106. The first isoclinic chart was constructed by Wilcke, in 1768; a second and improved one, was published by Hansteen, in 1819, and the most recent map is that of General Sabine, published in Johnston's *Physical Atlas*, 2nd Edit.

I.—Magnetic Intensity.[*]

The Intensity or force of the earth's magnetism at various points is determined by observations on the time of vibration of the magnetic needle. An immense number of observations have been made all over the globe, which have been tabulated by General Sabine, and arranged according to geographical position. We have already seen the importance which Sabine attaches to the element of Intensity as a guide to our knowledge of terrestrial magnetism. The first observations, by which changes in the intensity of the earth's magnetic force, depending on change of place, were established, were those of Lamanon, made during the expedition of *La Perouse* in 1785-87. These were followed by the observations of De Rossel ; but Humboldt was the first to establish, during his travels in the equatorial regions of America in 1798—1804, that the increase of magnetic force coincides with the increase of latitude. Since then observations for determining the magnetic force have been made at various parts of the world by travellers and navigators, including Hansteen and Due along the coasts of Africa and America ; those of Lutke in a voyage of circum-navigation, 1826-29 ; those of Hansteen,

---

[*] For an historical account of observations on magnetic intensity, the reader is referred to General Sabine's *Report, Brit. Assoc.*, 1837.

Due, and Erman in the North of Europe and Asia, in 1827-29; those of Fitzroy on the Shores of South America and the Southern Hemisphere; and those of Freycenet and Duperrey in the voyages of circum-navigation of the *Uranie* and *Coquille.*

But, probably, the greatest gains to magnetic science were those made by Sir James Clark Ross, in the *Erebus* and *Terror*, during 1840-43, in the Antarctic Regions, followed by those of Captains Moore and Clark in the same part of the globe; by the magnetic surveys of General Lefroy in the British Possessions of North America, and by those of Captain Elliot in the Indian Archipelago in 1846-50.

J.—Chart of Isodynamic Lines.

The most perfect chart showing the Lines of Equal Intensity which we possess is that originally constructed by General Sabine; and, in examining this chart, we find that the magnetic force increases, generally, as we recede from the Equatorial, towards the Polar, Regions; attaining a maximum value at two points, or *foci*, in each hemisphere, of unequal intensity.

In the Northern Hemisphere the position of the stronger *focus* has been very closely determined by

General Lefroy; it is situated in British America in N. lat. 52° 19′, and 92° W. long. The place of the weaker, or Siberian, focus is situated in 59° 44′ N. lat., and 118° E. long., as deduced from the observations of Erman.

The *foci* of the Southern Hemisphere are much nearer to one another. Their positions, as deduced from the observations of Sir James Ross, are, the stronger in lat. 64° S., and 138° E. long. ; and the weaker in nearly the same latitude, and 125° W. long.*

K.—Sabine's Deductions.

The following are the leading deductions regarding Magnetic Intensity, as laid down by Sabine :—

(1.) The Lines of Equal Intensity are not parallel with the Lines of Equal Dip, and the difference is systematic.

(2.) The Lines of Intensity in the northern hemisphere indicate the existence of two centres of attraction of unequal force. One of these, and the less powerful, is situated in Siberia; the other, and more powerful, in the region of Hudson's Bay.

---

* Lloyd. *loc. cit.,* p. 111.

(3.) The two Foci of Magnetic Attraction in the northern hemisphere are not at opposite points in reference to the terrestrial pole ; their difference in geographical longitude being about 200° measured across Greenland and Norway, and 160° across Behring's Straits.

(4.) The Magnetic Intensity is unsymmetrically distributed in the meridians of the northern hemisphere ; this is a consequence of the two centres not being exactly opposite to (that is at a distance of 180 degrees from) each other. If we imagine the hemisphere to be divided into two equal sections by a plane coinciding with the meridians 100° and 280° W. long., the western section will contain both centres of attraction, and a higher measure of Intensity is spread over its meridians than in the corresponding latitudes in the eastern section.

(5.) The Lines of Intensity in the southern hemisphere have a general analogy with those of the northern. Thus the highest Intensity in the district of Hudson's Bay or New York is matched by the nearly equal value of the Intensity at Hobart Town, being 1·80 in the former, and 1·82 in the latter, while the geographical latitudes of the two places are nearly identical. It is almost certain that there are two Foci of Unequal Intensity in the southern, as in the northern, hemisphere.

L.—Line of Weakest Magnetic Force.

The Line of Weakest Magnetic Force on the globe has been traced with great care by Sabine.* It is an irregular line, running round the globe between those lines indicating units of Intensity. These latter are the weakest isodynamic lines which run unbroken round the globe, and they lie, except in the Pacific and Atlantic areas, in close proximity to the terrestrial equator. In the meridians of 110° and 260° they approach each other closely, but in those of an intermediate position they recede, and enclose spaces of still weaker intensity. In the middle of the largest of these, being a position most remote from all the four centres (or poles) of attraction, we have a space of weakest intensity anywhere to be found on the globe : its approximate position, as determined by Admiral FitzRoy, is a little south of the Island of St. Helena, where the Intensity was found to be 0·84. Erman has since found a spot, south and west of this island, where the Intensity registered 0·8, the position of Minimum Intensity. The Line of Weakest Magnetic Force, called *The Magnetic Equator*, consequently passes a little south of St. Helena—thence it ranges westward across the South Atlantic, striking the Continent of South America in lat. 20° S., and taking a course slightly north of west, leaves it at about lat. 10° on the coast of

* *Rep. Brit. Assoc.,* 1837, p. 75.

Peru. At 100° W. long. it crosses the terrestrial equator, and, keeping the same direction as far as 165° E. long. where it recedes to its most northerly position, takes a due westerly course by the extreme north end of the Islands of Borneo and Sumatra in lat 6° N., and proceeding westwards, strikes the African Coast near the equator, and crosses this continent in a S.W. direction till it re-enters the ocean in lat. 17° S; thus completing the circuit of the globe. It is to be recollected that the Magnetic Equator indicates the position at every point where the attraction of the North and South Magnetic Poles of the earth exactly balance each other, and at which there is in consequence no dip of the needle. The Magnetic Equator coincides with that of " No Dip " throughout three-fourths of the circumference of the globe; in the remaining fourth (across the South Atlantic Ocean and part of Africa) the two lines diverge considerably, owing to some cause still unknown.

M.—The Mariners' Compass.

Navigation in ancient times was carried out under difficulties and disadvantages unknown to us. Ships either coasted along within sight of land, or were guided to their destination by the position of the sun by day, or of the pole star by night; and they seldom ventured out of sight of land for any length of time. In the Æneid of Virgil, and the voyage of St. Paul in the Acts of the

Apostles,* we have vivid representations of the character
of navigation before the invention of the mariners' com-
pass. This most useful of modern inventions has
enabled the sailors of modern times to launch forth into
the trackless deep, and cross the widest oceans more or
less directly for the port of destination ; and we may go
so far as to say that without its aid navigation, as it is
carried on now from port to port across the ocean, would
be next to impossible. We have already seen that the
use of the mariners' compass was known in the thirteenth
century of our era, and that Columbus, in crossing the
Atlantic in 1492, made use of it for directing his course,
though ignorant of its variation in consequence of a
change of position.

The mariners' compass scarcely needs description, as
almost everyone is familiar with its appearance. It con-
sists of a needle permanently attached to a card divided
into 32 " points," or *rhumbs*, so that the needle and card
move together. The needle turns on a pivot, and is
contained in a glass box suspended in gimbals, in order
that it may preserve the horizontal position. In the best
ships' compasses several magnetized needles are placed
side by side, as it is found that the indications of such
compound needles are more reliable.†

---

* Chapter xxvii.

† The most beautiful and perfect compasses hitherto made are those of Sir
William Thomson, whose light compass dials have surmounted the serious
errors which were inseparable from the ordinary heavy forms.

N.—Theories of Terrestrial Magnetism.

The earliest theory is that of Gilbert, in which it is supposed that a magnet in the middle of the earth extends from one magnetic pole to the other. Halley endeavoured to supplement Gilbert's theory by supposing two magnets of unequal strength crossing each other at the earth's centre to be the cause of terrestrial magnetism. The theory of the two magnets and four poles was ably defended by Hansteen.* According to the hypothesis of Biot, the direction and intensity of the force exerted by the globe, at any point of its surface, will be the same as that emanating from a single magnet, whose axis passes through the centre of the earth in a direction perpendicular to the magnetic equator. Lloyd raises an objection to Biot's hypothesis, chiefly on the ground that the line of Least Intensity does not coincide with that of No Inclination, which ought to be the case if Biot's hypothesis, and, we may add, that of Gilbert, was true. But it will be found as a matter of fact that these two lines very closely coincide throughout a distance of about three-fourths of the globe's circumference, or 265°, between the East Coast of Africa and the centre of South America. It is in the Southern Atlantic alone that a marked deviation between the two occurs ; and it is remarkable that it is

---

* Ferguson, *Electricity*, p. 57.

over this region that there is a marked decrease in intensity as indicated by the Isodynamic Lines. In this region there is evidently, therefore, a local disturbing force, of the cause of which we are ignorant; but the objection to the view that the earth is a magnet seems not to be sustained. In addition to the above hypotheses, which have a basis of agreement, may be stated that of Barlow, who considered that the earth acts on the needle as if currents of electricity traverse its surface from east to west. This view is essentially different from those preceding.

PART IV.

DISTRIBUTION OF PLANT AND ANIMAL LIFE ON THE GLOBE.

CHAPTER I.

INFLUENCE OF CLIMATE.

A.—Connection between the Organic and Inorganic Kingdoms.

WHEN we consider the influence which organized beings, especially those inhabiting the ocean, have exerted on external inanimate nature; how strata forming the interior of continents or rising into high mountain ranges were originally elaborated by living forms ; or, again, how important a part has been played by plants, not only in decorating the surface of this fair earth, but in influencing the character of the climate, we cannot but admit that it is difficult, if not impossible, to draw a rigorous line of demarcation between the inorganic and organic kingdoms. Therefore, in a treatise

like the present it seems desirable, even at the risk of excessive brevity, to devote a few pages to the consideration of the main facts regarding the distribution of plant and animal life over our globe.

B.—Climate the most Potent Agent in this Distribution.

It will be recognized at once that climate is the most potent agent in determining this distribution. For, although the actual inhabitants of most parts of the world are the direct descendants or representatives of those which come down from the Tertiary periods of geological history, still, as the climates have been considerably modified during this long interval, especially over the Northern Hemisphere, only such forms as were capable of adapting themselves to the varying climatic conditions have survived to the present day. Vast migrations of animals have taken place in the latest Tertiary times. As Dr. Wallace has shown, the present inhabitants of the African Continent are the descendants of those which in the Pliocene period inhabited the Europasian Continent, but who, on the approach of the Glacial Epoch, were driven southwards by the advancing cold; and having invaded Africa, dispossessed the smaller aboriginal inhabitants which are now represented by those of Madagascar and neighbouring islands.

C.—Variation in Climate, owing to Changes in Level of Land.

Climate not only varies with the latitude and with the distribution of land and sea, but with the altitude of the land above the sea ; so that, even within the tropics and under the equator, we meet with successively colder climates as we ascend the mountains from the burning plains, corresponding to zones of latitude on proceeding towards the Polar Regions from the Equatorial. In consequence of this beautiful law, first, if I mistake not, pointed out by Humboldt, plants and animals representative of those of different latitudes are to be found at successive levels as we ascend, for instance, from the plains of Northern India to the heights of the Himalayas, or from the plains of Central Africa to the summit of Kilimandjaro ; or, again, from the valley of the Amazon to the crest of the Andes. Thus it may be mentioned that Darwin noticed near the summit of the Cordillera, on the eastern side, almost under the Equator, numbers of plants and animals absolutely the same as, or closely allied to, those of Patagonia.*

---

* *Naturalist's Voyage*, p. 327.

CHAPTER II.

BOTANICAL GEOGRAPHY.*

A.—Classification of Plants according to their requirements of Heat and Moisture.

Keeping in view what has already been stated re-garding the conditions of plant distribution, we find that the vegetation of the world is capable of being divided according to the views of A. de Candolle and Mr. Baker, F.R.S., into four broad groups, as follows :—

(1.) *Macrotherms* ; or, plants existing at low eleva-tions within the tropics, and needing hot-house culture in our own climate.

(2.) *Mesotherms* ; or, plants of the sub-tropical zone, and needing green-house culture in our climate to protect them from frost and snow.

(3.) *Miotherms* ; or, plants of the cool-temperate latitudes or zones ; and hardy in our climate.

---

* For the following pages on this subject I am indebted to Mr. F. W. Burbidge F.L.S., author of *The Gardens of the Sun* (1880).

(4.) *Microtherms* ; or, plants of the cold or Arctic-Alpine zone ; needing protection from drought, full sun heat, and light at the sea-level in our climate.

These groups fairly represent the natural thermal capacities of plants ; and the next point is to form similar groups showing their needs as regards atmospheric moisture, as follows :—

(1.) *Xerophilous Plants* : These can live in climates where the air contains usually but little moisture (Examples—Succulent plants and desert scrub, *Cacti,* &c.).

(2.) *Hygrophilous Plants* : These can thrive only in climates containing a great deal of atmospheric moisture. (Timber trees, filmy ferns, palms, and tall-growing vegetation in general).

(3.) *Noterophilous Plants* : These are intermediate in constitution, and bridge over the gulf between the first two groups. (Many bulbous and tuberous-rooted plants, also some pseudo-bulbous orchids, &c., which endure alternately a wet, very hot and a dry season).

Although it is possible within certain limits to classify plants into sections according to their requirements of

heat and of moisture, it must be distinctly borne in mind that no such abrupt divisions exist in a state of nature. The gorgeous epiphytal orchids of the equatorial regions are represented by terrestrial species in the meadows of Britain and Europe. The common Viper's Bugloss of our Wicklow Shores *(Echium vulgare)* is represented by a tree 20 feet high in the Canary Islands or in Madeira ; and the herbaceous Horehound of our gardens forms a shrub 10 or 12 feet high in South America. Other plants, often only of annual duration in our gardens, such as the Castor Oil and Mignonette, are not only perennials but usually form good-sized shrubs on the African shore. Nature, in the broad sense, abhors abrupt distinctions ; and we really find a gradual transition from the pole to the tropics, both physically and physiologically ; in form as well as in size and function.

B.—Effect of Elevation on Plant-Distribution.

As has been shown, latitude or temperature influences plant-distribution at or near sea-levels as we recede from the equator, and we will now note how elevation affects plant-distribution in a similar manner. The best way of showing the gradual transition which frequently takes place from the intertropical to the temperate or Alpine types of vegetation is by describing the ascent of a

mountain of from 10,000 to 12,000 feet, or even much higher, within the tropics.

It is in a tropical forest that one best feels the force of Darwin's phrase, "struggle for existence," and the truth of the statement, as seen in the tropics, has again and again been attested by the observations of Kingsley, Wallace, Roezl, and other travellers.

You sail your boat over a warm and glassy sea, and enter a river or creek and push your way inland. On the sandy shore, their thickened stems often washed by the tide, are rows and groups of graceful cocoa-nut palms, their cylindrical stems shooting up into the air, their deep green apical plumes waving in the breeze, and their cooling rustle falling pleasantly on the ear when the thermometer is 95° or more in the shade. Everywhere around you are the effects of heat and sunlight, and the deluge of tropical rains. Rose-apples scent the warm air; and Mangoes, Mangosteen, Durian, Jack and Bread fruit, dainty Mandarin oranges hang in luxuriance on the trees around the palm-leaf huts and dwellings. In the swamps you see Rice, Tapioca, *Caladia*, and the thick stemmed Sago-palm. On higher and drier ground, Nutmeg, Clove, and other spices, Tobacco, Sugar-cane, and Hill-rice cover the cultivated patches. Again you push through the Mangrove swamp near the shore, and enter the lowland forest itself, and are in the shade with tree trunks towering all around you. It is like a new

world ; the trees rise out of an undergrowth of Ferns, Aroids, and small Palms; and there are boles of every size, some smooth and branchless for 100 feet, others rough barked and clasped by Llianas and parasitic Figs of many kinds. Now and then you find the rotten remains of a giant of the forest that has been strangled by a lacoon-like fig tree that originally was a seed dropped in a crevice of its bark by a passing bird. There is one point worth noting as to the fate of seeds which fall in a dense tropical forest. They must either lie dormant in the soil below, awaiting the opportunity afforded by a tornado or a forest fire, or if they germinate they must climb for their lives. " Climb or die," is often Nature's fiat to her offspring ; and the seeds of figs of many kinds, of Rattan palms, and of a hundred kinds of Llianas obey her injunction, and clamber up to the leafy roof of what has been called Nature's cathedral. Here and there are openings made by a tornado, and a hundred giants lie prostrate, their tops covered with Orchids and other epiphytes, often of the utmost beauty. Everywhere around you the most luxuriant leafage rises from the ground, Ginger, Bamboo, Aroid, and Palm, and you feel as if all the botanical gardens of Europe had been spread out around you in the sunshine. You pass on, still ascending from the shore, and you hear the flutter of wings overhead ; you look upwards, and find that the parrots and pigeons, or hornbills, are in a fruit tree, the head of which is 100 feet or more above your own. A step or two further, and a fallen husk or two, an ominous

rustle of the branches, and a suppressed chattering, tells of the monkeys at their dinner. On you go, a snake here, a gorgeous butterfly or two there, or the flight of a strange bird, being all that detracts your attention from the rampant vegetation around. Now the ground rises more steeply, and as you scramble up the rocky pathway, and creep over the thickly interlaced roots of the trees, you gradually become aware of more light and air ; for the trees are less dense and tall than on the lowlands by the creek below, and it is also cooler. You look at your aneroid, and find you are over 4,000 feet above the sea. You push on another 1,000 feet, and the trees are still smaller, and there are grassy knolls and openings here and there, and a few weedy *Compositæ* give quite a homely look to the sides of the path. Between 2,000 to 5,000 feet you reach the most luxuriant part of the forest, every old water-course and ravine being filled with tree ferns and mosses of exquisite beauty. No forms of tropical vegetation are more striking than the Palm, the broad-leaved Banana, the Bamboo wands rising in straight and leafy masses 50 or more feet in height, and last, but most lovely of all, the black velvety-boled Tree-ferns, crowned with their exquisite feather-like fronds. At 5,000 feet you may see a group of Horsetails (*Equisetæ*) in a wet ditch ; at 6,000 feet a kind of Raspberry (*Rubus rosæfolius*) and other species of less moment ; at 7,000 feet Cypresses, or *Dacrydia*, and Rhododendra appear, while in a cool spot at your feet rise some giant mosses, reminding one of a colony of

seedling pines.   At 8,000 feet the trees and shrubs be-
come scrubby and laden with moss and lichen, or with
delicate filmy ferns.   You are in the cloud zone, and
cool mists or drizzling rains are frequent.   European
forms of vegetation appear more abundantly.   Now there
is more open ground, sedge or grass covered ; and from
an elevated point you can see through a cloud rift the
mass of forest stretching far below you right out to the
coast line, and the blue sea dotted with islands and coral
reefs beyond.   Around you species of Sow-thistle
(*Sonchus*), *Gnaphalium* or Cud-weeds, *Umbelliferæ*,
Buttercups, *Artemisia*, *Plantago*, *Hypericum* and Chick-
weed abound, so familiar and home-like in aspect,
while far below you are the epiphytal orchids, the
Pitcher plants (*Nepenthes*), and the heat-loving Palms
so characteristic of the tropics.

C.—Influence of Latitude.

It will be readily observed that elevation and latitude
must alike be studied in relation to the distribution of
plants, seeing that on the upper portions of mountains
in Java, in Central and Northern India, and in Abyssinia
are found species which belong to the same genera, and
actually represent other species common to the higher
mountains of Europe.   A familiar example is the
" Bridal Everlasting " of the Swiss Alps (*Leontopodium*

alpinum), more often known as the " Edelweiss," which is represented by a nearly allied species (*L. grandiceps*) on Mount Cook in New Zealand, and has also been found more recently growing high upon the slopes of a mountain in the Sikkim Himalayas. On the higher Alps and Pyrenees are plants identical with those of Lapland, and not to be found in the intervening plains. On the tops of the White Mountains in United States again we find species identical with those of Labrador ; thus elevation in the one case, and latitude in the other, supply the climatic conditions essential to their existence. Seeing that we find plants belonging to the *Miotherm* and *Microtherm* divisions at high elevations throughout warm temperate, and even in inter-tropical, regions, the question as to how they came to be there is one which quite naturally presents itself; and both Darwin and Wallace agree in referring their distribution to a somewhat recent glacial epoch. At that period Britain and portions of Europe and North America, now enjoying a temperate climate, were covered with ice and snow, and had a climate like the Arctic Regions to-day. The only vegetation was naturally that now known as of the Arctic-Alpine or Microthermal type, such as *Dryas*, *Saxifrages*, low-growing willows, *Lichens*, and the dwarf *Silene*. As this cold epoch gradually passed away, and the snowy glaciers receded up the mountain slopes, the Alpine plants receded also, "clinging then, as now, to the margins of perpetual snow." Thus the same species, having died out in the warm plains, are only to be found

on the mountain tops of Europe and America, or in the North Polar Regions. Mr. Darwin further believed that this depression of temperature was sufficient to drive temperate forms of plants by elevated routes to cross the Equator, and to reach the Antarctic Regions where they are now found.*

---

* Further information on this subject will be found in Hooker's *Himalayan Journals*; Darwin's *Origin of Species*, chap. ii.; Wallace's *Malay Archipelago*; Baker's *Botanical Geography*; and Mr. Burbidge's *Gardens of the Sun (Borneo)*.

CHAPTER III.

ZONES OF PLANT-LIFE ON THE HIMALAYAS.

A.—THEIR DESCRIPTION.

As supplementary to the above graphic review of the geographical distribution of plants, I will only add, by way of illustration, an outline description of the zones of plant-life as developed on the flanks of the giant Himalayas, for which we are indebted to the labours of Sir J. D. Hooker.[*] As this distinguished naturalist has pointed out, the plants of the Western Himalayas are chiefly representative of the European flora ; that of the Eastern, of the flora which extends into China and Japan. The succession about to be described belongs to the central region, that of Sikkim, leading up to the snow-clad Kinchinjunga itself. The following zones may be determined approximately as we ascend from the plains of the Ganges :—

---

[*] *Himalayan Journals ;* and *Illustrations of Himalayan Plants* (1855).

(1.) *Zone A (of Macrotherms) between* 2,000 *and* 4,000 *feet.*

Jungle grasses and scrub, large Bamboos, Bananas, the *Pandanus, Bauhinia,* and species of Fig. The crests of the rocky ridges and ravines are adorned with scattered pines, *Pinus longifolia ;* Orchids, sometimes epiphytal, are abundant, of which the beautiful *Vanda Cathcarti* and *Dendrobia* of several species require special mention.

(2.) *Zone B (of Mesotherms) between* 4,000 *and* 6,500 *feet.*

Here we meet, of Palms a species of *Calamus, Plectocomia,* and *Phœnix acaulis ;* also *Cycas pectinata* and the India-rubber fig. In the lower part of this zone flourishes the noblest of all oak trees, the *Quercus lamellosus,* towering to a height ranging from 40 to 60 feet into the air.

(3.) *Zone C (partly of Mesotherms and Miotherms) between* 7,000 *and* 10,000 *feet.*

Here the main features consist of Rhododendrons, Magnolias, Laurels, Oaks, Maples, Walnuts and Figs. The *Rhododendron arboreum,* which ranges from 8,000 feet

and upwards, is a beautiful and conspicuous tree ; but grander still is the *R. argenteum*, which raises its blossom-crowned head to a height of 40 feet from the ground. Of Magnolias we have *M. Campbelli*, quite a forest tree ; also *Talauma Hodgsoni* and *Michelia Cathcarti*, belonging to the same natural order. Along with the forest trees is a beauteous undergrowth of flowers and shrubs, such as Hydrangea, bushes of *Aucuba, Skimnia*, and *Helwingia*, and flowers, as *Convallaria, Paris*, and *Begonia*. Of this last-named plant, now such a favourite in our greenhouses, there are about 12 species confined to the eastern part of the Himalayas, and very abundant in the Khasia mountains. The zone we have just described must be considered the most imposing and characteristic of the Central Himalayas.

(4.) *Zone D (partly of Miotherms and Microtherms) from* 10,000 *feet to the Snow-Line.*

Here we notice plants resembling those of Northern Europe and parts of the British Isles, as rushes, grasses, sedges, Alpine Rhododendrons (representative of the *R. ferrugineum* and *R. hirsutum* of the Alps), Potentillas, Honeysuckles, Polygonums, dwarf Junipers, Gentians, Sedums, Composites, and Umbellifers. The *Rhododendron nivale* reaches to the Snow-Line at 17,000 feet above the sea, where we almost reach the limits of vegetation.

CHAPTER IV.

CULTIVATED PLANTS AND CROPS OF TROPICAL, SUB-TROPICAL, AND TEMPERATE CLIMATES.*

(1.) *Macrotherms.*

(Cultivated at 1,000 to 4,000 feet elevation in tropical regions.)

Yam	Brazil-nut	Granadilla (fruit of
Sweet Potato	Mango	Passiflora spp.),
Arrowroot	Custard-Apple	Jujube
Sago Palm	Rose Apple	Betel-nut
Cycads	Guava	Vanilla
Rice	Banana	Indigo
Maize	Bread Fruit	Gamboge
Sorghum	Date	Logwood
Panicum	Tamarind	Henna
Cocoa-nut	Papaw	Oil Palm (*Elais*)

---

* This list has been kindly drawn up by Mr. Burbidge.

Castor Oil	Cinnamon	Sanseviera
Seasamum	Capsicum	Rosewood
Sugar	Cotton	Teak
Nutmeg	Corchorus	Ebony.
Clove	Broussonetia	Coffee

(2.) *Mesotherms and Miotherms.*

(Cultivated in sub-tropical regions.)

Rice	Vine	Agave
Maize	Fig	Senna
Wheat	Pomegranate	Tea
Millet	Olive	Opium
Lentil	Cinchona	Melon
Cicer	Tobacco	Gum Arabic
Fenugreek	Aloe	Hemp

(3.) *Microtherms.*

(Cultivated in cool or temperature regions.)

Wheat	Pear	Linseed
Oat	Apricot	Potato
Barley	Gooseberry	Turnip
Rye	Currant	Beet
Pulse	Quince	Onion
Plum	Medlar	Cabbage
Apple	Loquat	And other cruciferous crops.

In India all three of the above regions are represented by elevation, and one may pass from the Mango and Sugar, Spice, or Sago producing plains, through the cooler Cashmere valley with its Vines and Melons, until in the high Thibetian valleys we find barley fields and orchards of Apricot trees.

CHAPTER V.

DISTRIBUTION OF ANIMAL LIFE.

A.—Introductory.

The distribution of animal life follows laws similar to those of plants; but, owing to the greater sensitiveness of plants to atmospheric changes, with less regularity. The subject is one of great interest, and of a scope too wide to permit of being fully treated here. Some leading features regarding the distribution of the higher forms of animals may, however, be placed before the reader.* The animals which at present inhabit the land-surface of the globe are the descendants of those which lived during the Pliocene Period. In some cases they are modified in form, but their distribution has been, also, profoundly modified in consequence of the physical

---

* For fuller information on this subject, the following works may be consulted Andrew Murray, *Geographical Distribution of Mammals* (1866); A. R. Wallace, *Geographical Distribution of Animals*. 2 Vols. (1876); Ernest Haeckel, *Naturliche Schöpfungsgeschichte*, or Prof. Lankester's Translation, *The History of Creation* (1876); *Encyclopædia Britannica*, 9th Edit., Art., *Distribution*.

changes which have occurred over the region of the Northern Hemisphere between the Pliocene and the present epochs—changes to which reference has already been made when dealing with the subject of the distribution of plants.* During the Pliocene epoch, the continents of Europe, Asia and North America were inhabited by races of animals which are now chiefly found in Africa and the Inter-tropical regions of America, while some of the species have altogether disappeared. Thus the aboriginal Horse, which during the later Pliocene epoch roamed over the plains of North and South America, was exterminated, the progenitors of the present wild horse of the Pampas having been introduced by the Spaniards. The Mammoth and Mastodon, which frequented both the Europasian and American continents, and the noblest of stags, the *Megaceros Hibernicus,* which abounded in the glades and pasture lands of Europe and the British Isles, have all disappeared. But far greater was the change which took place in the distribution of the Mammalia at the commencement of the Quaternary period. The advancing cold of the Glacial epoch, gradually augmenting, drove the inhabitants of Europe and Asia southwards into Africa, and those animals only remained behind which by their constitution were suited to withstand the rigour of an arctic, or sub-arctic, climate. Keeping this point in view, we have a

---

* See *ante,* pp. 244 and 252. On this subject the reader is referred to what has been written in my *Sketch of Geological History,* p. 130 (1887)—London: C. W. Deacon & Co.

key to the existing distribution both of animal and plant life on the land-surface of the Northern Hemisphere.

B.—ZOOLOGICAL REGIONS.

For purposes of description, and as, in a large degree, actually representing the geographical distribution of mammalia and birds, the surface of the globe has been separated out into Six Zoological Regions, originally proposed (in 1857) by Dr. P. L. Sclater, and adopted by Dr. Wallace, as, of all the hitherto proposed systems of distribution, the most natural and convenient. They are as follows:—

(1.) The Palæarctic Region, containing 31 families of terrestrial mammals, and including Europe to the Azores and Iceland ; also, all temperate Asia from the Himalayas and west of the ·Indus, together with Japan and China to the watershed of the Yang-tse-Kiang; also a small portion of North Africa and Arabia.

(2.) The Ethiopian Region, with 40 families of terrestrial mammals, including all Africa south of the tropic of Cancer, as well as Southern Arabia, Madagascar and adjacent islands.

(3.) The Indian (or Oriental) Region, with 31 families of mammals, and including India and Ceylon, the Indo-

Chinese countries and Southern China, and the Malay Archipelago as far as the Philippines, Borneo and Java.

(4.) The Australian Region, with 14 families of mammals, and embracing the southern portion of the Malay Archipelago, Australia, New Zealand and the tropical islands of the Pacific as far east as the Marquesas.

(5.) The Neotropical Region, with 26 families of mammals, and including the whole of South America and adjacent islands, the West Indies, and the tropical regions of Central America and Mexico.

(6.) The Nearctic Region, with 23 families of mammals, and including all temperate and arctic North America, with Greenland.

C.—Barriers which Limit the Distribution of Animals.

The range of animals is determined by several physical barriers, some of which are connected with temperature and climate; others with the distribution of land and water. Of all the barriers to the migration of terrestrial animals, the great oceans are the most effective; and this is due, not only to their great extent of surface, but

to their great geological antiquity ; owing to which, races which have been inhabitants of widely disconnected continents during Tertiary times, have still remained isolated from each other down to the present day. Mountain ranges, when of great elevation and unbroken by wide and easily passable valleys, form natural barriers to the migration of many animals ; and this chiefly on account of the change of temperature and climate which takes place on ascending from their bases towards their summits. Large rivers are to a smaller extent found to define the range of certain animals ; as are also deserts, marshes and open plains. But in tropical regions the forests constitute the limiting ranges of a large number of animals, to whom the shade, perennial foliage, and fruits are absolutely indispensable. Such forests are, in fact, the homes of the most characteristic tropical faunas, and their limits form dividing lines between those which are very distinct from each other. The barriers, however, which define the limits of mammals and reptiles are often overpassed by birds, such as the Eagle and the Vulture, and some whose great powers of flight enable them to surpass the highest barriers of the land. Seabirds have also a very wide range, as have also birds of passage.

D.—Prevalent Animals of the Six Zoological Regions.

(1.) *The Palæarctic Region.*

The higher prevalent mammalia consist of hollow-horned ruminants (*Bovidæ*), seven genera; horses and asses; the Bactrian camel of Asia; several species of deer; the chamois and saiga-antelope; also sheep and goats; cats, wolves, foxes, bears and swine; many smaller groups, as weasels, badgers and otters, hares and rabbits. Seals abound along the coasts of the British Isles and Northern Europe, as also in the Black Sea and Caspian. The birds of this region are abundant both in variety and number. Eagles, hawks and vultures; grouse, pheasants; many water-birds, and numerous little warblers, such as nightingales, thrushes, redbreasts and larks, which are almost the companions of man, and lend a charm to the woods and glades bordering his dwellings.

(2.) *The Ethiopian Region.*

This region, being wholly tropical, is characterised by a more varied fauna than that of the preceding region. As it includes nearly the whole of the African Continent, it is pre-eminently the home of the larger mammals. It

abounds in elephants, rhinoceroses, hippopotami, giraffes, zebras, buffaloes and antelopes—some of large size; numerous carnivores, of which lions, leopards, hyænas and jackalls are the most conspicuous. It contains seven peculiar genera of apes, three of lemurs, numerous insectivora, rodents and *Viverridæ*. Reptiles abound in the form of crocodiles, lizards and snakes. Birds of great variety and beauty characterise special districts, such as the ostrich, the eagle, and the vulture; the Flamingo and Egyptian Ibis in the valley of the Nile; numerous fly-catchers, shrikes, sun-birds, weaver-birds, starlings and larks.

(3.) *The Indian (or Oriental) Region.*

Though of smaller extent than the Ethiopian, this region is so greatly diversified by forest-vegetation, islands and promontories, as to afford conditions very favourable to the preservation of animal forms; and contains, therefore, a fauna peculiarly rich and varied. The larger mammals bear some resemblance to that of the Ethiopian region, to which they are closely allied. Both possess anthropoid apes, elephants, rhinoceroses, large felines, buffaloes, and abundance of civets. But the Indian region abounds in deer and bears, and some special forms, such as the Malay tapir. The birds of this region are singularly abundant, varied and beautiful. More than 340 genera of land-birds inhabit this region,

of which number 165 are peculiar to it. Reptiles are also very abundant, as are also insects of gorgeous colouring. A tropical sun imparts to this region an amazing richness of colouring amongst the representatives of the animal kingdom ; and, combined with abundant moisture, conduces, also, to a luxuriance of foliage and beauty of blossom amongst the plants and forest-vegetation which adorn the valleys and mountain slopes.

(4.) *The Australian Region.*

This region presents to our view a fauna by far the most specialized and impoverished of any on the surface of our Globe. The cause of this is due to terrestrial isolation. The mammalia consist only of marsupials, a group representative of geological Mesozoic times, together with a few bats, rodents, and mice ; animals which may have accidentally gained an entrance to the islands.

Birds, as might be expected, are not so specialized as the mammals, as a large number of almost cosmopolitan families extend into parts of Australia ; yet there are no less than sixteen families characteristic of this region, amongst which are the *Apterix* and the Emu, the former an inhabitant of New Zealand. The lories, the mound-builders, the cockatoos, the lyre-birds, the honey-suckers, and birds of Paradise are also special and

representative forms. A number of struthious birds (as the *Dinornis*) forming two families, and sometimes attaining a gigantic size, have only recently become extinct in New Zealand. Many of the genera of reptiles, amphibia and fresh-water fishes are peculiar to the Australian region; the border land of the Celebes islands, however, contains some forms common to the adjoining Oriental region.

(5.) *The Neotropical Region.*

This region is one of the richest on the globe; yet, in common with the Australian region, it contains some low types of mammalia and birds, which seem to have come down from geological times. Monkeys are abundant, many of them with prehensile tails; bats are also numerous, including the vampire bat; the carnivora are not numerous; and the place of the ungulates is taken by a few species of tapirs, peccaries, llamas and deer. Small rodents are abundant, and the edentata form the most specialized group of the region, and include the sloths, the armadillos, and the ant-eaters; lastly, we find the marsupial opossums, which are most abundant in the tropical regions of South America.

The birds of this region are wonderfully rich, and no less than 24 entire families are peculiar to it, including

the condor, the largest of the vulture tribe. The reptiles include snakes, lizards, and tailless batrachians.

(6.) *The Nearctic Region.*

The fauna of this region presents a general resemblance to that of the Palæarctic region; yet there are considerable differences. The mammalia are represented by bears, elks, bisons, sheep, lynxes, wolves, martens, flying-squirrels, and marmots. The prong-buck and mountain goat are peculiar to the region. The beaver is an inhabitant of the northern rivers, and the *Ovibos*, or musk-sheep, is confined to the Arctic regions. In the squirrel family, the prairie-dogs are peculiar; and the *Tamias*, or ground squirrel, is very characteristic, though also found in Asia. The coasts and islands of the Arctic seas are inhabited by white bears, walruses and seals.

Of birds about forty or fifty genera are peculiar and characteristic, amongst which we notice such well-known forms as thrushes, wrens, crows, woodpeckers and grouse. Amongst the larger birds turkeys, the ruffed grouse, and crested partridges are peculiar.

The reptiles are more numerous than in the Palæarctic region. There are about a dozen snakes, including the well-known rattle-snake (*Crotalus*). Fresh-water fishes are numerous and peculiar.

E.—Man's Place in Nature.

The great exception to the distribution of animals, as determined by climate, is man himself, who extends his range from the Equator to and beyond the Arctic Circle, and from the tropical coasts and valleys to the limits of perpetual snow. Hence it is clear that the intellectual mind of man, as distinguished from the instinct of the brute creation, has rendered him independent to a great degree of climatic influences. By suitable clothing and by other appliances he is able to cope with the rigours of a climate like that of Lapland or the Coast of Greenland. Man's place in nature is diverse from that of other animals. To him the whole world lies open, and the riches of creation have been placed at his command by the Great Creator Himself. "The earth hath He given to the children of men," are the authoritative words accompanying the gift—a gift indeed often abused or neglected, but one which, when rightly used, is capable of indefinite multiplication, and of producing most precious fruit. Man has himself vastly altered the face of the globe; in some cases in the direction of degrading or destroying, in others of improving and embellishing. By cutting down or burning forests, he has converted extensive tracts of fertile soil into desert wastes; nor has he been more sparing of the works of his own hands. The ruined cities of the ancient historic world attest the de-

structive powers and propensities of man as exercised
towards his fellow-man.

In the preceding pages we have endeavoured to follow
some of the operations of natural forces in their varied
workings, and we cannot have failed to notice from time
to time the admirable arrangements and adjustments of
the parts of that wonderfully complex mechanism we call
" Nature," held together by the master force of gravita-
tion, and consisting of innumerable parts all working in
connection with each other ; all necessary for the perfect
working of the whole ; all adapted to the purposes they
fulfil.   Applying to the cosmic system the processes of
reasoning which, as intelligent creatures, we apply to
all the events of our every day life, we cannot but recog-
nize behind the structure of the universe the hand of
Him " Who hath created all things, and for Whose plea-
sure they are and were created."

PHYSIOGRAPHY.

INDEX.

PHYSIOGRAPHY.

INDEX.

AUTHORS QUOTED.

INDEX TO AUTHORS QUOTED.

New Books and New Editions

Imperial Folio—Measuring, when opened out, 17½ FEET in length and 22 inches in width, and printed in *TWELVE* Colours in the highest style of Chromo-Lithographic Art, Price £3 3s.

DEACON'S

SYNCHRONOLOGICAL
CHART OF UNIVERSAL HISTORY

WITH

Maps of the World's Great Empires

&c., &c.

ACCOMPANIED BY A

COMPLETE GEOLOGICAL DIAGRAM OF THE EARTH

DRAWN BY

PROFESSOR EDWARD HULL, M.A., LL.D., F.R.S.

THIS Work depicts in graphic and artistic form, and at one view, the origin, rise and progress of all Nations, from the Creation to the present day. The principle upon which it is constructed is an attempt to utilise the service of the eye in the study of History, whose essential unity is in this way stamped on the mind. By means of its synchronological arrangement and by a series of ingenious devices a continuous pictorial record is presented of all the leading events of the World's History, in the precise order of time, in the precise degree of importance, and in the precise relationship to one another, wherein they actually took place. Although the Chart is full and comprehensive, its plan is so simple, that decade by decade and century by century, each event with the whole of its contemporaneous surroundings can be clearly seen, and the Procession of the Ages traced. The mass of information given is skilfully grouped and adjusted, and its component parts withal so clearly distinguished by brilliant colour illumination, that the imagination, thus aided, can have little difficulty in transforming the dead records of the past into striking and living realities.

PUBLISHED IN TWO DISTINCT STYLES:—

"**PORTFOLIO.**"—Mounted on Linen. Elegantly and Artistically Bound.
"**ROLLER CHART.**"—Mounted on Canvas, with Mahogany Rollers.

Each with a full and comprehensive Key or Plan in seven languages.

SEE TESTIMONIALS ON OPPOSITE PAGE.

Amongst numerous TESTIMONIALS from Men of Eminence and Scholarship we have received the following :—

HAWARDEN CASTLE, FLINTSHIRE, *November 23rd, 1887.*
The Rt. Hon. WM. EWART GLADSTONE says :—
"Your Synchronological Chart has the appearance of being a work of much interest."

BISHOPTHORPE, YORK, *December 12th, 1887.*
The ARCHBISHOP of YORK (Rt. Hon. and Most Rev. WM. THOMSON, P.C., D.D., F.R.S., &c.) says :—
"Your Historical Chart is very elaborate and comprehensive, and the main purpose in view seems to me to have been successfully carried through. By appealing to the eye, it secures the important aid of visual impressions, which are striking and easy to retain. As to the matter of exactness, it appears to possess that quality. It should rank high amongst those luxuries of education which smooth the path of our grandchildren, but which were denied to us. The work must have been prepared with very great pains and outlay, and I wish it every success."

DUFFRYN, MOUNTAIN ASH, S. WALES, *December 13th, 1887.*
The Rt. Hon. Lord ABERDARE, G.C.B., P.C., F.R.S., &c., President of the Royal Historical Society, says :—
"Your handsome Synchronological Chart is a great work, apparently executed with skill and care. It is well calculated to relieve the Historical Student from much laborious research, for which the authorities are not always at hand."

DEESIDE, CHESTER, *November 19th, 1887.*
The BISHOP of OXFORD (Rt. Rev. WM. STUBBS, D.D., LL.D., &c.) says :—
"I am glad to welcome your beautiful and valuable Synchronological Chart of History as a most useful instrument of education, and at the same time an illustration of the progress of the arts by which it is produced. I wish it every sort of good success."

2 CONNAUGHT PLACE, W., *November 22nd, 1887.*
The Rt. Hon. Lord RANDOLPH CHURCHILL says :—
"The compilation of your Synchronological Chart must have involved an enormous amount of labour and research, and I have no doubt that it will prove of valuable assistance to those who make history their study."

CAMBRIDGE, *July 19th, 1888.*
J. R. SEELEY, Esq., M.A., Professor of Modern History, Cambridge University, says :—
"My opinion respecting your Chart can only be that it is *splendid* and *wonderful.* I cannot be wrong in saying that a marvellous amount of historical information has been brought together and presented in a wonderfully ingenious and vivid manner, which is extremely well-adapted for the teaching of history."

SCHOOL BOARD FOR LONDON, VICTORIA EMBANKMENT, W.C., *January 28th, 1888.*
The CHAIRMAN of the SCHOOL BOARD for LONDON (Rev. JOSEPH R. DIGGLE, M.A.) says :—
"I have carefully examined your Synchronological Chart of Universal History and have found it as accurate and trustworthy as any arrangement of the kind is ever likely to be. The plan is extremely simple, and easily understood, and the value of it to those who have to teach history, and to adult students, is very great. I wish the enterprise every success."

KING'S COLLEGE, CAMBRIDGE, *November 17th, 1887.*
OSCAR BROWNING, Esq., M.A., Chairman of the Council of the Royal Historical Society, says :—
"The skill and ingenuity with which the events on your Synchronological Chart are depicted to the eye are very praiseworthy."

ST JOHN'S TRAINING COLLEGE, BATTERSEA, *December 13th, 1887.*
The Rev. CANON DANIEL, M.A., Principal, Battersea Training College, says :—
"Your very valuable Synchronological Chart of Universal History is constructed on scientific principles, and must prove highly helpful to young students. It is impossible to study the history of any country satisfactorily apart from that of other countries. Your Chart will enable students to see what was going on simultaneously in different countries and in what way they influenced each other."

CROWN 8vo, SUPERIOR BINDING.

SKETCH OF UNIVERSAL HISTORY.

ANCIENT HISTORY. By PROFESSOR RAWLINSON.
MEDIÆVAL HISTORY. By PROFESSOR STOKES.
MODERN HISTORY. By PROFESSOR PATTON.

Each of these Three Volumes, containing a full account of one period, is complete in itself, and form together a Sketch of Universal History in its entirety.

Apart from numerous Testimonials from influential men, the Reviews which have appeared in the leading Journals throughout the United Kingdom would, if printed *in extenso*, contain as much matter as several complete newspapers. Want of space permits us to give only the following brief

EXTRACTS FROM OPINIONS OF THE PRESS.

" The amount of labour expended in the preparation of these works must have been immense." — *Aberdeen Journal.*

" Thoroughly to be recommended on the score of accuracy and clearness."—*Athenæum.*

" The three volumes form an historical trilogy of considerable merit."—*Belfast Northern Whig.*

" The work of eminent hands."—*Birmingham Daily Post.*

" There has been no work which fills the place now taken by these volumes."—*Bristol Mercury.*

" An absolute necessity to the historical student, while for the general reader it is a very *embarras de richesses*."—*Cambridge Chronicle and University Journal.*

" The three volumes will be found most interesting and useful, either for school use, private study, or general reading."—*Daily Chronicle.*

" All three volumes bear obvious signs of research and may well prove of real service to those who desire an accurate general knowledge of the History of the World."—*Daily Telegraph.*

' Readable and most valuable for purposes of reference."—*Dublin Daily Express.*

" People desirous of obtaining quickly a general view of the history of any particular period could not do better than refer to this work."—*Dundee Advertiser.*

" May well find a place in any library." —*Eastern Morning News.*

" Comprehensive in design, convenient in arrangement, and handy in size. May be accepted as worthy of nigh favour."—*Glasgow Herald.*

" The volumes can be heartily recommended."—*The Globe.*

" The elaborate chronological tables and indices will be very convenient for finding in a hurry the exact date of any leading event in the world's history."—*The Guardian.*

"Three remarkable volumes by distinguished professors."—*Hampshire Post.*

" A most valuable contribution to literature."—*Hull Daily News.*

"Evidence of the minute accuracy with which the work has been done may be found in the extent of the survey, which comprises alike Chili and Peru, Venezuela and Paraguay."—*John Bull.*

" The work has been done on lines carefully worked out beforehand."—*Leeds Mercury.*

"We have seldom risen from the perusal of any historical work with greater pleasure."—*Leeds Times.*

" Contain a vast amount of information."—*Liverpool Courier.*

"The whole series is in the highest degree trustworthy."—*Liverpool Mercury.*

"Have read the three volumes, and have no hesitation in recommending them as most useful, most instructive, and most interesting." — *London Figaro.*

" It is difficult, if not impossible, to over estimate the value of these volumes, which stand out markedly from the crowd of kindred publications."—*Manchester Courier.*

"These volumes are not the work of mere hack compilers, but of men whose known work in the historical field is of recognised value." — *Manchester Examiner and Times.*

" Must prove of great service to those who desire an accurate general knowledge of the History of the World."—*Newcastle Daily Chronicle.*

" Three admirable volumes, placing the history of the nations and peoples of the world within such a compass as an ordinarily cultured mind can grasp."—*Newcastle Leader.*

"The work is highly recommended and is bound to be popular."—*Northern Chronicle.*

"A bird's-eye view of the course of the human race from the Creation down to the present date."—*Norwich Eastern Daily Press.*

" Not only is the general plan excellent, but the details have been dovetailed into it with the greatest ability.

All the great historical movements of the world, from the Creation to 1887, are succinctly chronicled."—*Oxford Times.*

"Professors Rawlinson and Stokes have reputations which we have neither the will nor power to disparage, and Professor Patton, it is easy to see, has taken a great amount of pains with his subject."—*Pall Mall Gazette.*

"The whole work forms an admirable epitome—in all its most important details—of the World's History."—*Public Opinion.*

"Will be cordially welcomed by student and general reader alike."—*The Rock.*

"It is a bright, interesting, lively narrative, making attractive reading for its own sake."—*School Board Chronicle.*

"The work of three distinguished scholars. Rapid as the story is, and wide as is its sweep, it does not fail to gather up all the important leading events of recorded history."—*The Scotsman.*

"Presenting in a clear, concise, and continuous narrative every event worthy of record in the annals of human history."—*Scottish News.*

"They rank exceedingly high among the educational publications of the year."—*Sheffield Daily Telegraph.*

"Probably at once the most complete, the most popular, the most reliable, and altogether the most fascinating epitome of universal history extant."—*Sussex Daily News.*

"This work supplies a real desideratum." - *The Tablet.*

"Form a valuable addition to the cheap educational literature of the day."—*Western Daily Mercury.*

"These volumes give an admirably succinct and accurate survey of the world's history. May they circulate largely and be widely read."—*Western Morning News.*

"A triumph of artistic genius."—*Whitehall Review.*

SKETCH OF ANCIENT HISTORY.

By PROFESSOR RAWLINSON. Price 7s. 6d ; by Post, 8s.

"Professor Rawlinson has been very successful in his attempt to present in brief compass the stories of Greece and Rome."—*Aberdeen Free Press.*

"Professor Rawlinson has done his work in a masterly manner."—*Belfast Northern Whig.*

"Relates the history of the various nations and states of the earth in a series of parallel narratives."—*Birmingham Daily Times.*

"By a careful reference to this volume the student may soon master not only the dates of each particular epoch, but its features, and arrange before his mind's eye the current events as they flow on from the remotest times."—*Bristol Times and Mirror.*

"This sketch is by an author of the highest eminence in this branch of study."—*Cambridge Chronicle and University Journal.*

"Professor Rawlinson has done his work with rare skill, learning, and industry."—*Chester Chronicle.*

"The leading features of the story of each great division of the human race are clearly and intelligently summarised."—*Cork Examiner.*

"The history of various nations and states during the time indicated is told in a series of parallel narratives."—*Daily Chronicle.*

"Gives a history of the great Egyptian, Assyrian, and Persian monarchies more complete and succinct than is elsewhere easily accessible."—*Dublin Daily Express.*

"Is a plain, straightforward statement, which eschews the daring speculations of the most recent school of historians."—*Eastern Morning News.*

"A clear and trustworthy record of events."—*England.*

"Supplies an excellent outline history of the ancient nations and states, written in a lively attractive fashion."—*Freeman's Journal.*

"To the student of history Professor Rawlinson's work will prove invaluable."—*Hull Daily News.*

"The history of Rome strikes us as the best part of the work ; it is fuller, and in some portions, such as the difficult relations between Sulla and Marius, Pompey and Cæsar, and the real meaning of the great civil wars, it is particularly clear and vigorous."—*Leeds Mercury.*

"The Camden Professor of Ancient History at Oxford is one of the most likely writers to be familiar with the fruits of latest researches, and his sketch of ancient history is written 'up to date.'"—*Liverpool Courier.*

"The Camden Professor of Ancient History at Oxford has not failed to avail himself of the fruits of recent discoveries."—*Liverpool Daily Post.*

"It contains a digest of Canon Rawlinson's works on Oriental Monarchies, sufficient, probably, for all ordinary purposes."—*Literary World.*

"Canon Rawlinson has earned for himself a high position in the historic world of letters." —*Manchester Courier.*

"A monument of the industry of its author."—*Morning Advertiser.*

'The study of History is reduced by this volume to something like a scientific method."—*Oxford Times.*

"Embodies the results of the latest investigations."—*Public Opinion.*

"It records in pithy, yet full and accurate manner, the rise and fall of Nations and the development of those great Empires peculiar to this epoch of the World's History."—*The Rock.*

"Professor Rawlinson presents in comparatively few pages a summary of all that has yet been discovered concerning the most ancient monarchies of the world. His sketches of Grecian and Roman history are skilfully written."—*Saturday Review.*

"Professor Rawlinson's volume utilises the wealth of knowledge that has come to us in our own time by the deciphering of the old inscriptions in the East."—*School Board Chronicle.*

"The name of the Camden Professor of Ancient History is a sufficient guarantee for the excellence of the first volume."—*The Scotsman.*

"This Epitome is very skilfully executed, and its utility to the student is much enhanced by the synchronological and other tables, and the elaborate index."—*Scottish Leader.*

"Ancient History is by Professor Rawlinson than whom there is, perhaps, no greater living authority."— *Sheffield Daily Telegraph.*

"It is a marvellous story, marvellously well told." — *Sussex Daily News.*

"In the sketch are embodied the results of those recent investigations which have thrown so much light upon a subject of which it was previously well-nigh impossible to construct an authentic record." — *Western Daily Mercury.*

"The learned Oxford Professor has embodied the result of the latest researches and discoveries, and thus the volume is without doubt the completest that has yet been published."— *Western Morning News.*

SKETCH OF MEDIÆVAL HISTORY.

By PROFESSOR STOKES. Price 5s.; by Post, 5s. 6d.

PRESS OPINIONS.

"Gives a good idea of the political history of the Middle Ages—the rise of the Mahometan power, the tumultuous times of the German Empire, the Crusades, England as a Continental Power, &c."—*Aberdeen Free Press.*

"Mediæval history from the death of Theodosius the Great to the fall of Constantinople in A.D. 1453, is compactly treated by Dr. Stokes."—*Aberdeen Journal.*

"A useful feature in Dr. Stokes' volume is a list of authorities at the head of each chapter, and the book is on the whole singulary free from errors."—*Athenæum.*

"A good summary of the period, and is provided with an admirable chronological table and index." — *Belfast Morning News.*

"Professor Stokes has availed himself of the best authorities, and laid under contribution the latest and most authentic historical works."—*Belfast Northern Whig.*

"Gives a lucid summary of the chief facts of the Eastern and Western Empires, the Gothic and Lombardic Kingdoms, the early history of England, Ireland, and Scotland, the Carlovingian Empire, the Saracenic or Mohammedan Empire, with brief references to Russia, Poland, Spain, and China."—*Birmingham Daily Post.*

"The author's diligence in research and capacity for sifting, sorting, condensing and arranging the crude matter out of which coherent and scholarly historical treatises are made

will be deemed worthy of appreciative recognition. Not only the principal peoples of Europe, but Asiatic India and China are included in this comprehensive view."—*Church Review.*

"The sequence is orderly and the style lucid."—*Church Times.*

"The growth of England during the Middle Ages will be found succinctly traced by Professor Stokes."—*Daily Chronicle.*

"Marked as it was by a wonderful accession to humanity of light and learning, this period is comprised within the compass of a very moderate-sized volume in which are shown all the main facts of interest."—*Daily Telegraph.*

"A model of careful compression."— *Dublin Daily Express.*

"The work is done clearly and straightforwardly."—*Eastern Morning News.*

"The history of all the peoples who can be said to have had a history, is narrated in parallel accounts, special attention being directed to the nations and institutions which by their influence and importance gave to these times their chief characteristics."— *Glasgow Herald.*

"Professor Stokes carries the narrative through the difficult years between the defeat of Stilicho and the coronation of Charles the Great."— *Leeds Mercury.*

"The centuries in question were crowded with matters of interest, and Professor Stokes seems to have in-

diciously utilised the best authorities at first hand."—*Liverpool Courier.*

"Mediæval History is succinctly expounded by Dr. Stokes."—*Liverpool Daily Post.*

"Covers the great mediæval period which saw the birth and development of the Papal power, the origin and conquests of Mahometanism, the rise and decay of feudalism, the invention of gunpowder, the printing press, and the mariner's compass, and the commencement of those adventures in navigation which soon afterwards culminated in the discovery of a new world across the Atlantic."—*Liverpool Mercury.*

"Dr. Stokes, the Professor of Ecclesiastical History in the University of Dublin, has earned for himself a high position in the world of letters."—*Manchester Courier.*

"Professor Stokes is a man of weight and authority in the realm of history."—*Morning Post.*

"Supplies a need which has been much felt."—*The Nonconformist.*

"Dr. Stokes has made good use of the many materials at his disposal, and has succeeded in producing a very useful and able volume."—*The Rock.*

"The tone of the work is at once popular and philosophic. It is no mere compilation, but a strong, comprehensive grasp of the strange and sometimes inexplicable story of the thousand years that elapsed between the fall of the Ancient Civilizations and the beginning of those which are still in the course of development."—*School Board Chronicle.*

"Professor Stokes, of Dublin, is a high authority on mediæval history."—*The Scotsman.*

"Furnishes a very useful bird's-eye view of the most prominent events of the Middle Ages."—*Scottish Leader.*

"Nothing could be more admirable than Professor Stokes' treatment of the Crusades."—*Scottish News.*

"The volume of 'Mediæval History,' from 395 to 1493, a period of great importance in the development of mankind, and in other respects most interesting, is just as thorough, treating even of the history of China, about which to the majority of persons very little is known."—*Sheffield Daily Telegraph.*

"An excellent idea is given in this work of the Dark Ages—that time when great things were attempted and many notable things accomplished." *Western Morning News.*

SKETCH OF MODERN HISTORY.

By PROFESSOR PATTON. Price 7s. 6d.; by Post, 8s.

PRESS OPINIONS.

"There is a certain charm in the rapid ride through the centuries. The rapid succession of great events stirs the blood, and the absence of troublesome philosophising must be a great relief to the *dilettante* reader of these days."—*Aberdeen Free Press.*

"A very complete work."—*Belfast Morning News.*

"This portion of the work is undoubtedly, from its very nature, the most interesting and the most difficult to accomplish."—*Belfast Northern Whig.*

"Not only is the historic narrative clear, concise, and fair for ordinary readers, but the mass of facts and figures is so well arranged as to be useful for reference, and to be readily found by the copious index."—*Birmingham Daily Post.*

"It is surprising what a great amount of knowledge Professor Patton has managed to compress into the limits of the work. The advantage of being able to study the history of the various countries contemporaneously is obvious. By this means a real and lasting acquaintance with the broad interlacing facts of history is certainly more likely to be obtained than by the ordinary methods of studying the annals of several countries separately."—*Birmingham Daily Times.*

"In each period contemporary history is set forth, so that the student has not to travel, so to speak, in his studies, but has the features of Italian, French, German, Russian, Polish, and Ottoman History, etc., mapped out before him. All is set forth with lucidity and interest."—*Bristol Times and Mirror.*

"Each page bristles with names and places, and is sprinkled freely with dates. We consider the work one of high value, and to the mature student of history it is full of suggestiveness and stimulation."—*Chester Chronicle.*

"We recommend this book as a good and useful compendium of modern history. The sketch of American History is particularly well done."—*England.*

"The advancement and consolidation of the states into which the world is now divided are clearly traced, and the progress of literature, science, and the arts in each period noted."—*Glasgow Mail.*

"This work will certainly take rank as a valuable addition to the student's library, and will be a lasting tribute to the skill and knowledge of Professor Patton."—*Hampshire Telegraph.*

"It is not difficult to find adequate histories of different countries; it is a hard matter to find a real World History."—*Leeds Mercury.*

"The volume of Modern History is especially well done—the 'Sketch' in many places giving way to most interesting and succinct detail, and thus making the work especially valuable."—*Leeds Times.*

"Professor Patton boldly and faithfully sketches modern history and he has produced a well-executed piece of work."—*Liverpool Daily Post.*

"Professor Patton has produced a useful and accurate book."—*Morning Post.*

"The name of Professor Patton is an ample guarantee for the thoroughness and reliability of any work he may undertake."—*Manchester Courier.*

"Though Professor Patton is less well known than his distinguished collaborators, his volume on Modern History proves that he is not unworthy to be associated with them."—*Manchester Examiner.*

"The general arrangement and classification are alike excellent."—*Public Opinion.*

"Describes in a clear, vigorous, and intelligent style, every important event in the world's march towards a higher and nobler civilisation during the past four centuries."—*The Rock.*

"Contains a vast number of facts. A carefully executed piece of work."—*Saturday Review.*

"The author handles this period with ease and freedom, and deals with the points which are, even to the present time, made tender by controversy and party feeling with boldness and with reasonable discretion. It is a most useful sketch of these four-and-a-half centuries of progress and civilisation."—*School Board Chronicle.*

"A piece of painstaking and useful work, and supplies what is often much needed."—*Scottish Leader.*

"The description of the scenes of the French Revolution, with all its horrors, is singularly graphic and impressive."—*Scottish News.*

"The result of the author's labours is a summary of Modern History which, for dexterity in the marshalling of dates and facts, for power, directness, and simplicity of expression, and for general interest and accuracy, is probably unequalled by any book of its kind yet offered to the public."—*Sussex Daily News.*

"Will be found extremely interesting reading, the romance of history receiving picturesque treatment from the facile pen of Professor Patton."—*Western Daily Mercury.*

"Such a volume as this is invaluable—for to understand intelligently the many complex problems that vex national life to-day, it is needful to have an accurate knowledge concerning events of the last few hundred years."—*Western Morning News.*

"THE GLOBE WE INHABIT."

Uniform with the Histories, Price 3s. 6d.; by Post, 3s. 9d.

SKETCH OF GEOLOGICAL HISTORY

BEING

The Natural History of the Earth and of its Pre-Human Inhabitants.

By PROFESSOR EDWARD HULL.

EXTRACTS FROM OPINIONS OF THE PRESS.

"Dr. Hull's work far surpasses our expectation."—*Aberdeen Free Press.*

"The work of an expert."—*Aberdeen Journal.*

"Generalization, not in every case unallied with rashness, has always been Professor Hull's strong point, and this characteristic has stood him in good stead in giving life and interest to the speculative restorations of the land and sea of past periods which abound in these pages."—*Athenæum.*

"All the periods are described from the Azoic Age to the Neozoic and Quaternary, and the epoch of man."—*Belfast Morning News.*

"The book will not only be of value to the student, but it will be of interest also to the general reader who has not made a special study of geology."—*Belfast Northern Whig.*

"Contains a mass of facts."—*Birmingham Daily Post.*

"We can recommend the work with the greatest confidence."—*Board Teacher.*

"It is a fascinating story, and here we have it told in brief by Professor Hull."—*Bristol Mercury.*

"Professor Hull gives a clear and lucid summary of geological history, and the book is specially adapted for popular reading, since scientific words and terms are never used without explanation."—*Daily Chronicle*.

"Gives a plain and lucid statement of the facts of geology, as they are now generally recognised and taught."—*Dublin Daily Express*.

"Embodies the results of the most recent research."—*Dundee Advertiser*.

"A book which geological students of all grades will find useful."—*Eastern Morning News*.

"The clear account Dr. Hull gives impresses the subject on the mind with a distinctness not easily attainable.—*The Educational News*.

"The work is well done and in accordance with the latest theories on the subject."—*England*.

"The author enjoys a more than European reputation as a writer on geology."—*Exeter Flying Post*.

"There need be no hesitation in saying at once that this volume will enhance Dr. Hull's reputation as a competent teacher of science."—*Freeman's Journal*.

"Forms an appropriate introduction to the Universal History.—*Hampshire Post*.

"Remarkably concise and must prove exceedingly interesting to the geological student."—*Hull Daily News*.

"The student has here the very literary marrow of many ponderous volumes."—*Irish Educational Journal*.

"Professor Hull follows illustrious examples in preparing this abstract of a science which he has at his fingers' ends."—*Knowledge*.

"Professor Hull writes in a very lucid and pleasing style, quite unlike the didactic mode of scientific men generally."—*Leeds Times*.

"There is a good deal of unquestionably valuable information in these pages."—*Literary World*.

"Will ensure a sound elementary knowledge of geology, and admirably preface the way for more advanced study."—*Liverpool Daily Post*.

"This admirable little volume is a valuable addition (to the sketch of Universal History), and makes the set quite perfect."—*London Figaro*.

"There is no higher authority than Professor Hull, whose writings are familiar to everyone who has tried to understand the 'testimony of the rocks.'"—*Manchester Courier*.

"The author has succeeded in making the work both interesting and instructive, and it may be confidently recommended to those who require a reliable guide to the general principles of geology."—*Morning Post*.

"The book is drawn up in a clear and masterly manner." — *National Schoolmaster*.

"The book before us is a marvel of condensation."—*Nature*.

"Professor Hull's work is a *desideratum*, there being nothing exactly like it in the English language."—*North British Daily Mail*.

"A compact narrative of facts."—*Norwich Eastern Daily Press*.

"The information is brought down to the latest period of investigation." —*Oxford Times*.

"The work has been done with a clearness and fullness which is at once the evidence and the result of very complete knowledge." — *Practical Teacher*.

"The former volumes deal with recorded history, ancient, mediæval, and modern; this one is a sketch of the natural history of the earth before the animal man made his appearance upon the scene." — *School Board Chronicle*.

"A book from the pen of the author of 'Coal Fields of Great Britain' and of 'Contributions to the Physical History of the British Isles,' is sure to be full of interest, and as original as accuracy and the nature of the subject will permit." — *The Schoolmaster*.

"He who has mastered its contents will have laid an admirable theoretical foundation for the study of geology."— *Scotsman*.

"Undoubtedly presents a very useful summary of Geological History."— *Scottish Leader*.

"Professor Hull has grappled manfully with his difficulties and succeeded beyond all expectations."— *Sheffield Daily Telegraph*.

"Dr. Hull has aimed at the production of a sketch which shall contain the various epochs and their noteworthy fossils, and at the same time enable a student to apprehend that most suggestive and interesting subject,—contemporary history of geologic change. The sketch is written in a clear, forcible style, and its convenient size should render it popular." —*The Spectator*.

"The first complete summary of the historical portion of the strangely-alluring science of geology which has ever been published in the English language." — *Sussex Daily News*.

"The gist of all the information obtainable in matters geological has found a place in this work."—*Western Morning News*.

DEACON'S

BOOK OF DATES:

A Manual of the World's Chief Historical Landmarks

AND

AN OUTLINE OF UNIVERSAL HISTORY

BY

CHARLOTTE M. YONGE.

WITH   THIRTY-THREE   ILLUSTRATIVE   MAPS

BY

KEITH JOHNSTON, LL.D., F.R.S., F.R.G.S., &c., Geographer to the Queen.

The MANCHESTER COURIER *says:* —" The present volume contains in a convenient form a synopsis of the great events of the world, arranged so as to give a kind of bird's-eye view of the contemporary occurrences in different countries, and thereby impress upon the mind of the student a clearer idea of the relation that one country bears to another, and the influences that each has had upon the other. The first portion is devoted to a general outline of the history of the Ancient World, commencing with that of the three great races—the Semitic, the Aryan, and the Turanian—the settlements of the early tribes, the rise of the Greek kingdoms of Syria and Egypt, the Roman Commonwealth, and the Punic wars, followed by the development of the great Roman Empire, the rise of the Papal Power, mediæval Europe, the reaction against corruption resulting in that great religious revolution, the Reformation, followed by the various social and political revolutions of the last three centuries, and the changes in the boundaries of States as a consequence of the continental wars of 1848 to 1871. Under the head of " Historical Landmarks " we have (1) a series of synchronological tables of events under various dynasties from the year B.C. 2500 to A.D. 651, when Persia became absorbed in the Empire of the Mahometans ; and (2) a series of chronological tables arranged in periods from the death of Theodosius the Great, A.D. 395, to the present time, the most important occurrences in each country being grouped in the period to which it pertains.   An interesting feature, and one that forms by no means the least valuable part of the work, is a table setting forth the populations, religions, and governments of the world, with detailed particulars of the colonies and dependencies of the European and other States, with the years in which they were severally acquired—tables that may be read with profit by those who would look with indifference on the frittering away of our own empire, showing, as they do, the extent to which some of our continental neighbours, notably Germany, have added to their territorial possessions during the last few years.   The volume furnishes a handy and compact reference to the chief events of every country and State.   It contains a mass of useful information relating to each particular epoch, presented in a clear, concise, and readable form, and gives not only a comprehensive view of ancient and mediæval history, but an intelligible and continuous picture of Europe from the dawn of modern civilsation to the present time.   A vast amount of labour must have been bestowed in the preparation and in the arrangement of the subject matter, and, what is of the first importance, every care has been taken to secure accuracy of detail.   The work is accompanied by a series of carefully engraved maps—33 in all, commencing with that of Europe at the time of the Crusades, and culminating in a general survey of the existing state of the world."

Just Published, Crown 8vo, Superior Cloth Binding, Price 5/-, by post 5/6.

A TEXT BOOK
OF
PHYSIOGRAPHY
OR
PHYSICAL GEOGRAPHY

Being an Introduction to the Study of the Physical Phenomena of our Globe.

BY

EDWARD HULL, M.A., LL.D., F.R.S.

DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.
PROFESSOR OF GEOLOGY IN THE ROYAL COLLEGE OF SCIENCE, DUBLIN.

WITH COLOURED PLATES, MAPS, AND ILLUSTRATIONS.

In preparing this work, the Author has endeavoured to make it as complete and exhaustive as the limits assigned would permit, and a reference to the list of chapters given below, will show that the treatment of no subject falling under the designation of " Physical Geography," or " Physiography," has been omitted.

Without trenching further than could be avoided on the domain of Astronomy, some account of the Earth as a member of the Solar system has been given, and also a brief description of the early condition of the Globe. These fundamental problems having been disposed of, the physical phenomena observable on the surface of the earth as at present constituted, have then been dealt with. So wonderfully linked together, however, are all the parts of this stupendous whole, to which we give the name of NATURE, that it is impossible to deal with any individual section of it without, in some degree, having reference to other aspects of it than those immediately under consideration. Even the organic and inorganic kingdoms are so interdependent that the work would have been considered somewhat incomplete, had no reference been made to the Distribution of Animal and Plant life on the Earth's surface; and, consequently, the concluding Part has been appropriated to this most interesting and comprehensive subject. Where anything like full treatment of a special subject was found inconsistent with the scope of the present *opusculum*, copious references have been given to works in which it will be found more fully handled.

CONTENTS.

COMPOSITION AND STYLE:

A Handbook for Literary Students

WITH A

Complete Guide to all matters connected with Printing and Publishing.

Edited by R. D. BLACKMAN.

This volume sets forth and illustrates all the rules which should be observed by the young Author. These, if diligently practised, will enable anyone of ordinary intelligence to acquire for himself a clear and forcible style.

By way of introduction, and as a stimulus to the attention of the Student, a comparison is instituted between the opportunities and status of writers in bygone years and those which favour men of letters of the present day. The greatly enhanced material results which now attend a successful literary career are too obvious to need more than a passing mention here.

In the body of the work the Student is first warned against the improprieties which occasionally disfigure the pages even of good writers. In this connection the purely grammatical errors and peculiarities of expression, drawn principally from Foreign Idioms, which must be sedulously avoided by the merest tyro in the art of composition, are treated at such length and with such clearness of example as will ensure their entire future avoidance. The main lines along which the writer must travel to acquire propriety and precision of style are broadly indicated; and the care which is necessary in the employment of Synonyms, or nearly synonymous words, is brought home to the Student by suitable instruction.

His attention is then drawn to the proper construction of sentences—the key-stone to the arch of perfect composition—and he is afterwards introduced to the select body of authors, who, from the sixteenth century onward to the present time, have gradually and continuously built up our existing English style.

The Student is now in a position to profit by a detailed account of the niceties of composition comprised in the employment of the various Figures of Speech, to each of which an entire chapter has been devoted.

The foregoing directions are then combined in a general survey of the different kinds of style which mark the great masters in the art, and many sections are employed in placing before the Student the means whereby he may attain to the facile use of whichever of these styles he may prefer.

At each stage of the process, he is furnished with abundant examples, culled from the ancient and modern worlds of literature, of the excellencies he should imitate, and of the faults he should avoid; and his judgment is assisted by a lengthy and careful analysis of the style of some of the acknowledged masters of English composition.

An important feature in the present volume is the section devoted to practical hints on the technical and business aspects of composition and literature. Such information may indeed be found elsewhere in a scattered form, but it has not hitherto been embodied in a work of the present character.

The READING MERCURY *says:*—

"This work will be found useful to Students of Composition, as well as to inexperienced Authors who contemplate publication. The first part of the volume is devoted to remarks upon and illustrations of grammatical errors in writing, the structure of the sentence, the use of figurative language, and the various qualities of Style as exemplified by Standard English Writers. The illustrative passages from Roger Ascham to John Ruskin are arranged with care and judgment. The concluding chapters of the publication furnish practical advice with regard to the preparation of MSS., the relations of Authors, Editors, and Publishers, and the technical details connected with the printing and issue of new books.

65th THOUSAND. NEW EDITION.—Crown 8vo, handsomely bound, cloth gilt,
Price 2s. 6d. ; by post, 2s. 9d.

THE LETTER-WRITER'S VADE-MECUM

AND

DICTIONARY SUPPLEMENT :
A Complete Handbook to the Epistolary Art.

Edited by R. D. BLACKMAN.

The great success which attended the previous editions of this work has been such as to justify the publishers in endeavouring so to extend its scope as to appeal to a still larger section of the public than heretofore.

It was felt that something more was needed to secure the ultimate aim of the work ; and that to effectually assist those desirous of acquiring facility in the art of Letter-Writing, it was necessary to begin from the very foundation, and, by presenting to them in a convenient and compact form the most useful rules in every subsidiary branch of that art, to enable even the comparatively uneducated amongst them to practise it with ease.

With a view to stimulate curiosity, and to show what delightful results accrue from proficiency in that too rare accomplishment, an account of the most brilliant Letter-Writers of the World, and of their style and productions, is prefixed to the main body of the work. This is followed by a series of useful hints on those elementary subjects which should first engage the Letter-Writer's notice ; and some veritably *golden rules* are here set forth and illustrated by appropriate and forcible examples.

The next portion of the work is in reality an introduction to Composition and Style in their essential elements, and should receive an attention corresponding to their importance.

At this stage full explanations are inserted on all matters which bear on Punctuation ; and a full and useful chapter is introduced on the Blunders and Blemishes that most commonly beset the path of Young Writers in every department, and mar their best endeavours.

The work contains a complete list of the Participles of Verbs that can present the smallest difficulty as to spelling, every example being referred to the rule which affects it ; and a very full list of Homonyms is included. Other points, necessary to be observed, and therefore, useful to the Letter-Writer, for example, the Prepositions proper to be employed after particular Verbs or words possessing verb force are noticed at length.

To keep pace with the growing interest felt in technical terms and ideas, a list of those Greek Words, which, either in their original or a modified form, have been pressed into this service, will be found in its proper place.

In order to fully justify the title of Complete Handbook, a list is given—more complete and exact than any hitherto published—of the Forms of Epistolary Address, with full directions for beginning, concluding, and addressing letters to persons of all degrees, ranks, and denominations. A full account of the Order of their Precedence and the relative social position of the various grades in the service of the Crown is included in this section.

One of the most valuable divisions of the work, considered as a handy book of reference, is that devoted to Postal Information and cognate matters. The mass of details comprised in the many separate Official works on these subjects, are here shown in a single section.

The YORKSHIRE CHRONICLE *says :—*
" We are not aware of another book in the field of literature that embodies so much information as this one in so small a compass. It is styled on the title-page a ' Dictionary Supplement.' and ' A complete handbook of the epistolary art.' It is all that and much more, for a portion of its space is allotted to postal information and cognate matters. A more useful and handy book to be placed on the table of a poor man it would be difficult to find, but especially in the case of families where there are grown-up sons and daughters. It is to be hoped that it will have that large sale which it so richly merits."

DEACON'S
DICTIONARY OF FOREIGN PHRASES
AND
CLASSICAL QUOTATIONS:
A Treasury of Reference for Writers and Readers of Current Literature.

Edited by R. D. BLACKMAN.

It has been credibly reported in the press that a theatrical audience, having before them a drop curtain representing a Roman Villa, with the word "SALVE" prominently displayed upon it, one of them innocently enquired who was the maker of the *salve* which he supposed to be thus advertised. This is an extreme and somewhat ludicrous instance of a lack of knowledge which is prevalent to a much greater degree than is generally admitted.

Anyone who has received an education, however meagre, however strictly confined to his native tongue, is credited with a perfect acquaintance with most of the numerous foreign expressions and classical quotations which occur now more frequently than ever in current literature.

Although the number of Members of Parliament who can quote off-hand from their Iliad, or Æneid, or Horace, is fewer by far than half-a-century ago, yet we have quite recently heard an alderman cite Greek; and it may be safely affirmed that those who still possess these accomplishments are not indisposed to display them.

It is chiefly in the columns of the press and in works of a technical character that numbers of words and allusions, which are "caviare to the general," are to be found. Let us take at random a well-known evening paper. In a single leading article extending over a little more than a column in length, the following seven terms occur:—*Ménage, quid pro quo, savoir faire, in camera, amour propre, pro forma, infra dig.* Even popular works appear under such titles as *Fors Clavigera, Sartor Resartus, Altiora Peto, Vestigia, Omnia Vanitas, &c.* The decline in the study of the Classics, however, has considerably lessened the number of moderately well-educated persons who might, with the aid of a dictionary, spell out for themselves the meaning of such terms, and many of them are probably in the condition of the youth in the novel, who translated the motto, "*Toujours à Toi,*" by "*All Days to Thee,*" and of the reporter who took down phonetically the well-known phrase, "*Amicus Plato, amicus Socrates, sed major veritas,*" as "*I may cuss Plato, I may cuss Socrates, said Major Veritas.*" They might even regard *au sérieux* the late Henry J. Byron's clever absurdity, "*Honi soit qui mal y pense*"—"*On his walk he madly puns.*"

The difficulty we point out is largely increased because very many of the terms referred to are of the nature of idioms, or proverbial expressions, condensed very frequently to the last degree, and consisting sometimes of a mere catch-word which conveys to the initiated all that was expressed by the original author in a long sentence.

The contents of the work are grouped under the heads of the various languages from which they are drawn, and in every case the words and sentences are accompanied by their English equivalents. There are comprised LATIN, GREEK, FRENCH, ITALIAN, SPANISH, PORTUGUESE, and GERMAN.

In case of the quotations no pains have been spared to ensure their correct transcription and translation, and the meanings of the Foreign Phrases and Expressions have in many instances been brought out by original examples composed expressly for that purpose.

The LEEDS MERCURY *says:*—
"Writers and readers of current literature, especially the latter, will find this work of great use. A great many familiar phrases and sayings in Latin, Greek, French, Italian, Spanish, Portuguese, and German are brought together under appropriate divisions, and, being arranged alphabetically, reference is easy."

A Handsome Present.

40th Thousand.

COMPOSITION AND STYLE: A Manual for Students and Writers, with a complete Guide to all matters connected with Printing and Publishing. Price 5s.; by post 5s. 6d.

65th Thousand.

THE LETTER-WRITER'S VADE-MECUM: A Practical Manual of the Epistolary Art. Price 2s. 6d.; by post, 2s. 9d.

45th Thousand.

DICTIONARY OF FOREIGN PHRASES AND CLASSICAL QUOTATIONS: A Treasury of Reference for Writers and Readers of Current Literature. Price 3s. 6d.; by post, 3s. 9d.

These three books, printed on toned paper, can now be had in one Vol., half morocco extra, Mudie's superb binding, Price 12s. 6d.; by post, 13s.—*forming*

DEACON'S

"HANDBOOK for LITERARY STUDENTS."

MISS EMILY FAITHFULL *says :*—" I am very much pleased with your excelent book, and I can recommend it with great confidence. It is one of the best aids to literary success I ever saw, and will be found of great value to the studious aspirant."